JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CLX, NO. 5 80TH YEAR NOVEMBER, 1905

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CHEMICAL SECTION.

(Continued from Vol. clx, p. 295.)

*Mica and the Mica Industry.

BY GEORGE WETMORE COLLES.†

[The subject is treated in eight principal captions: Mineralogy, geology, geographical distribution, history, mining, uses, statistics and conclusions. The treatment is industrial rather than theoretical or scientific, and aims at setting forth the present, past and probable future of mica-mining in this and other countries. The first instalment dealt with the characteristics of the various species of mica, the second with the geology, and the present one with the geographical distribution, history, mining and milling and the uses of the micas.—THE EDITOR.]

III. GEOGRAPHICAL DISTRIBUTION.

Mica of the granitic varieties is, as previously mentioned, found in every country, almost in every district of any size, in the world, but commercial deposits are necessarily localized. In this review only commercial deposits will be considered.

At the present time three countries supply practically the entire output of the world, namely, India, Canada and the United

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States. No deposits of commercial importance are found in Europe, if we except some that have been found in Norway, but which, however, I believe to be too much honeycombed with intrusions to be of value, and at all events are not being worked; and the deposits of lepidolite or lithia mica in Bohemia, which are mined and smelted as lithia ore.* Brazil has within the last few years contributed slightly to the supply, but the output in this direction is probably sporadic and intermittent. Mica deposits, which could be utilized in default of others nearer the point of utilization, have been found in many of the newer countries, as for instance South Africa, Borneo, and the Philippine Islands, and it is not doubted that these and many other countries might become producers, if the sources now productive were to fail. But the abundance of the supply produced by the three countries mentioned would seem to shut out any new sources for a long while to come, as there is no question that these, especially India, can meet any demand for the mineral that is likely to arise for many years.

THE GRANITIC MICAS.

Large deposits of this class are found in very many countries in all parts of the world varying from an excellent quality downward. Wherever Archæan areas exist mica deposits are likely to be found, and these are invariably in dikes or veins cutting through country rock.

United States.

The Appalachian system, from Maine to Alabama, has been the principal source of production in this country, but numerous fine deposits have been found in various parts of the Rocky Mountain system, also, which may prove of greater importance as that section of the country grows in population and wealth.

Alabama.—Mica of good quality has been reported in the northwestern part of Randolph and adjacent parts of Cleburn and Clay counties, near Pinetucky, and thence the mica area

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The Bohemian lepidolite has none of the physical characteristics of mica which make it valuable, as it is not found in laminated crystals, but in cryptocrystalline masses. It is mica in a chemical sense only, and is may be questioned whether it should be termed mica at all.

extends southwest as far as Chilton county, all in the northwestern part of the State. None of these deposits have been worked, however, and cannot be mined profitably at present owing to distance from the railroad.

California.—Ledidolite deposits of the massive variety have been found near Pala in San Diego county at the extreme south of the State, and have been known and worked since about 1899. Their product is bought by Schieffelin & Company, of New York, for the manufacture of lithia. In 1901, lodes of white mica were found in the Piru mining district on Piru and Lockwood Creeks, Ventura county, known as the Barton Mica Mines, about fifty miles from Los Angeles and fifty-eight miles from Bakersfield, in Kern county. The mica is of rather mediocre quality.

Colorado.—Mica deposits exist in this State along the line of the Rockies, as in Fremont and Park counties, in the central portion of the State. Companies have been formed to operate them, but little if any mica has been actually produced.

Connecticut.—Lepidolite deposits are found in this State.

Georgia.—The mica dikes of the Appalachian extend into the extreme northwestern portion of this State but have not been worked.

Idaho.—A district known as the Robinson Mining District, in Latah county, about eighteen miles from the Northern Pacific Railway, was exploited in 1895, since which time increasing quantities of mica have been taken out. Mica is found in a pegmatic dike averaging six feet wide and which has been traced for over a mile. Crystals containing plates twenty-two inches by twenty-six inches have been taken out. In 1900 the product was about 1500 pounds of cut mica. It is notable that this is one of the few places in the world where mica has been mined in a systematic modern fashion. An adit 600 feet long has been driven to the lode, and a 500 foot raise. The cost of mining is stated at $5.00 per ton—presumably of rough and not trimmed or cut mica. Of course this gives no adequate idea of the actual cost either per ton of rock mined or per ton of finished product.

Maine.—White mica deposits have long been known to exist in Oxford County on the western edge of this State, especially around Paris. At Mount Mica, near that town, are found

mica dikes containing many tourmalines. Lepidolite is also found. Companies have been formed from time to time to exploit these deposits, but without commercial success. At Buckfield, East Woodstock and Rumford, all in the same county, the dikes are found.

Nevada.—Mica was discovered in Lincoln county in 1897, and sheets as large as 9x10 inches have been taken out. The deposits are worked from time to time on a small scale.

New Hampshire.—This State, up to 1869, was the principal and only commercial source of supply for mica in the country. The mica district extends through the western portion of the State from about the central to the southwest extremity, in Grafton, Sutherland and Cheshire counties. Mica has also been mined at Danbury, in Merrimac county, just south of the Grafton county line. The most important mines for many years were the Ruggles at Valencia and Palermo, the first of which was opened in 1803, and furnished for many years the bulk of the country's supply. Some $8,000,000 worth of mica has been taken from this mine, but it has now been closed for some years, partly owing to litigation, and partly no doubt to the declining values of the product. When the North Carolina district began to be exploited, in 1869, the knell of the New Hampshire industry was sounded. The product of New Hampshire fell off constantly, and for the last fifteen years the mines have been operated in only a fitful fashion. The development of the electrical industries, which rendered salable some of the small-sized mica, and the rise of the ground-mica industry, have alone prevented an absolute cessation of mica mining in this State. Most of the product has been shipped from Bristol, Canaan, Grafton, Rumney and Warren, in Grafton county, Danbury in Merrimac, and Alstead in Cheshire county.

New Jersey.—Near Bloomingdale, Passaic county, in the Blue Ridge Mountains, in the extreme northern portion of the State, mica deposits have been discovered, but an attempt at working them has not met with success.

New Mexico.—In the Cribbensville district, in the north-central portion of the State, not far from the Colorado line, there are mica deposits, which were worked on a small scale for several years, in the early nineties, but this has been abandoned.

New York.—In Westchester county, near New York City, there are coarse granites containing crystals of small size, and mistaken attempts have been made to work them, of course, however, without success.

North Carolina.—This State is now the most important domestic source of mica, and is likely to remain so for many years to come. At the present time it produces some 60 to 80 per cent. of the total output. No deposits yet found have produced superior "water-mica" for stove-glazing purposes, and it is doubtful whether any have equaled it. Of course mica of poor quality is found in North Carolina as elsewhere, and mica of many shades and varieties. Mica lodes are found in all the western counties, but the mica district proper is nearly limited to the strip running southwest and bounded by the Tennessee State line (Great Smoky Mountains) on the west, and the Blue Ridge on the east, and in this district the most important deposits are found in Mitchell, Yancey and McDowell counties. The history of mica mining in this district is given at length in a later section. The principal mines now operated in Yancey county, are the Ray, Westall, Joe Gibbs, Young and Bailey Mountain, and in Mitchell county the Cloudland—formerly Point Pizzle—Deake, Flat Rock and Mart Wiseman. Only a few of these are operated continuously, however. The last-named is one of the most famous both for rare minerals and also for large-sized crystals of mica, a single block of A-mica from this mine measuring six feet by three feet, and weighing about a ton.* The old Silvers mine (so called from the original prospects for silver), from which at least $30,000 worth of first quality mica has been taken, is not now being worked. Bakersville, the county seat of Mitchell county, is the local center for the mica business of that county, whence the mica formerly was transported by team to Marion, in McDowelll county, some twenty-eight miles away; and all of the Yancey county product went to Marion. Within a few years, however, a long-projected railroad down the Toe River has been put in and the product is now brought to the railroad, thus saving a large amount of hauling.

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*William B. Phillips, *loc. cit.*

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South Dakota.—Mica of commercial value was found in the Black Hills region of this State and Wyoming in the early nineties, and the deposits have been worked to a small but continually increasing extent up to the present time, notwithstanding the fact that the sizes are small and the quality of less value than the eastern mica. The principal district of exploitation lies on French Creek about six miles east of Custer City. The New York Mine, near Custer, is the principal one in this district. Further north, near Deadwood, Lawrence county, there are other mines, of which the Lost Bonanza is the most important producer. The Crown and Daly mines were opened in 1902. Most of these properties are owned by capital from Chicago and the Middle West. The South Dakota district is noted for the occurrence with the mica of spodumene. Cassiterite is also found in the mica dikes, and unsuccessful attempts have been made to mine it for tin.

Utah.—A deposit was opened in Salt Lake county in 1897, but no sheet mica of any value was reported.

Virginia.—Some mica credited to North Carolina has been produced from time to time in this State. The deposits lie principally in the southwestern portion of the State, west of the Blue Ridge. There has, I believe, been no production from this State during the last few years.

Washington.—A deposit was discovered and exploited in 1897 at Chelan Falls, Okanagan county, but the size was small, and it is not thought this can be successfully exploited, even assuming good transportation facilities.

Wyoming.—A little mica has come from the Black Hills region near the South Dakota boundary, but the principal mines are across the state line.

As will be seen, the only producing districts of importance to-day are in New Hampshire, North Carolina, South Dakota and Idaho, and of these New Hampshire will propably soon drop from the ranks. The future of South Dakota is doubtful, notwithstanding its present comparatively large production. The Idaho district is believed to have a possible future, and the North Carolina certainly remains to-day, and for aught that has

been yet found, is likely to remain for the future the principal producing State.

Canada.

There exist deposits of granitic mica in the neighborhood of the magnesian deposits of Ontario and Western Quebec; and these deposits are worked to a certain extent, notwithstanding they are of but mediocre value. The principal constituent of value in these dikes is the feldspar, which is worked for use in pottery. The really valuable white mica mines of Atlantic Canada lie in the region of the Saguenay River and Lake St. John, in Eastern Quebec.

Of the Ontario deposits there is one in Frontenac county, a specimen from which is shown in Fig. 6. In Ottawa county, Quebec, about sixteen miles north of Ottawa City, there is a dike containing lepidolite of good quality associated with green and opalescent feldspar and green and rose tourmalines.

The white mica mine most worked in this country is that at Villeneuve, twenty miles from Buckingham, which was worked by the British and Canadian Mining Company, Ltd., from 1884 to 1888, producing an annual average output of 9,000 pounds of cut sheet mica, which was nearly all consumed by the domestic market. Uraninite has been taken from this mine. This mine has not been worked for some years.

In the Saguenay River district, the principal deposits are in the canton of Bergeronnes and the adjacent cantons of Tadoussac and Escoumains on the Gulf of St. Lawrence; and also on the south side of the Saguenay, around the Upper Canard River. None of these mines has been worked to any great extent. The district suffers somewhat from lack of transportation facilities.

At Lake St. John and 250 miles to the north at the source of the Peribonca are likewise deposits apparently of very good quality.

On the north coast of the Gulf of St. Lawrence, 400 miles below the Saguenay at the mouth of the river Watshehoo there are some small islands containing large pegmatite veins offering mica prospects, but although well situated for operation, the deposits are poor.

Newfoundland has furnished samples of mica to the United

States, and there is no doubt that it is to be found there, but like all the minerals of that island, it remains unexploited.

In Western Ontario mica is reported from the Sudbury district, in Cleland and Gladman townships, and about twenty miles north of Lake Nipissing. Further west, on the border of Manitoba, in Rainy Lake county, white mica is abundant in several localities, notably on Falcon and Big Islands, and on Sabaskong Bay and on Rainy Lake.

The most important white mica deposits are probably those of Northern British Columbia, at and near Tête Jaune Cache, on the Canoe River, some 215 miles north of Kamloops, but these are so far from railway transportation as to place their exploitation practically out of the question for the present.

Dr. Robert Bell, of the Canadian Geological Survey, reports a good quality of mica from Hudson Strait, as well as from the Labrador coast, no definite information as to localities being given.

Mexico.

A deposit was exploited in 1898 to 1901 near Villa Corona, in Durango Province, North Central Mexico. There does not, however, seem any likelihood of the development of mica mining in that country. Mexico imports considerable mica from Europe.

Brazil.

For some years past mines have been exploited in the States of Minas Geraes, Bahia and Goyaz, which lie adjacent to one another in Eastern Brazil. The principal mines are in the State of Minas Geraes, not far from Rio Janeiro. These deposits are in pegmatite dikes, which run parallel to the Cayama and Popgais Mountains. Only two mines, Fonseca and Coronel Seraphino, are worked regularly, the last named yielding ruby mica. Small quantities of this product have come direct to New York, but the majority is exported to Europe; about $12,500 worth had been exported up to 1902, exclusive of domestic consumption.

Argentina.

Mica deposits have been exploited in Cordova Province in

the north central part of the country. Some sheets have been reported of a size 28x4 inches, but it is mostly small. About $11,000 worth has come to the United States in the years 1898 to 1900, and an additional amount was exported to Europe.

Samples of mica have been imported into the United States from Columbia and Guatemala and Cuba.

Europe.

Small quantities of mica are annually produced in Germany; this may be lepidolite from the Bohemian border, which is mined for lithia, of which Germany has been until recently practically the only producer. Great Britain produced some $8,600 worth of mica in 1897. Russia was from 1891-98 a regular exporter of mica on a small scale. The product was marketed on the Baltic, but no information is at hand as to the location of the producing district. A deposit called the Godfjeld mine has been exploited in Norway, near the southeastern coast, northwest of Kragerö.* The mica here was, however, worthless for many reasons. For many feet from the surface it was partially rotted, and below 100 feet it was likewise rotted or altered to a chloritic material. The mica, which is in a pegmatite dike cutting through mica, hornblende and tourmaline schists and gneiss, is of considerable interest for its defects, although worthless commercially.

Asia.

Burmah.—Mica has been produced and exported from this country, being shipped from Calcutta.

China.—An area of some fifty square miles, about fifty miles from Kiaochao Bay, was discovered by the Germans when they seized that point, and is said to contain "vast untouched deposits" of mica, though much discolored and broken by mineral inclusions.

India.—This is the great mica-producing country of the world. There are two principal regions, namely, that of Behar, in Bengal, and that of Nellore, in Madras, on the east coast; though small amounts have been exported from Bombay on the west coast—probably the production of Coorg, a small province in southwestern India, where mica has also been ex-

*Described by J. F. Wells in Colliery Guardian, Volume 78, page 32.

ploited. The Behar region has three principal districts, those of Hazaribagh, Gaya and Monghyr. In the first, some 250 mines have been opened, of which about sixty or seventy are operated annually. The mines of this district are partly in the Koderma Government Forest Reserve, and the rest are scattered over parts of Gadis-Gawan, Domchanch, Mushnudih-Byria, Dorunda and Satgawan. The principal mines are Dumcho-Gharanchi, Bochagta, Selboya and Kodama. They are from thirty-five to seventy miles from the nearest railway. The climate of this district is an execrable one, parched and desert for six months of the year, and deluged with rain for three months, during which time the mica mines cannot be worked.* The country is made up of a series of parallel ranges of low hills some 400 feet above the surrounding country and 1200 feet above the sea level. These run nearly east and west between Hazaribagh on the south and Gaya on the north, the Monghyr district being situated about seventy-five miles to the northeast of Gaya on the Ganges River. The country rock belongs to the later Archæan formations and consists of gneiss, quartzites and micaceous, hornblendic and tourmaline shists. These rocks are intruded by dikes of mica-bearing pegmatite, and others of fine-grained diorite, both series paralleling the strike and dip of the country rock, as elsewhere. The mica dikes are largely decayed and disintegrated for a distance of 100 feet and upwards, which is no doubt attributable to the excessive rains. Lepidolite is developed on a scale the like of which is seen nowhere else, there being but one white mica mine in Bengal (the Singur mine), and strange to say, in spite of its more frequent occurrence the ruby mica is valued at twice the price of the white mica. In Gaya the principal mines are Singur (white mica), Vita Chatkari, Bind, Govinpore and Korarama. The largest plates reported from the Bengal mines measure about 18x24 inches.

The Madras mica industry is practically new, the mines of Nellore having first become producers for export about 1895. The Nellore district in the coast region north of Madras was the first to be opened, and increased rapidly in importance.

*This is of course due to the monsoons which blow over the Himalayas for half the year and from the Arabian Gulf for the other half.

Since then two other mica districts have been opened, that of North Arcot to the west of Madras, and that of Nilgris in the southwestern part of the peninsula. The total production of Madras in 1902 amounted to 255 tons, nearly one-quarter of the total production of India. Some of the Madras mica is of immense size, plates five feet long and forty inches wide having been taken from the Itakuri mine of the Nellore district.

Japan.—Mica deposits occur on the Japanese islands, and exports have been made to this country from time to time, but there has been no steady export.

German East Africa.—Mica deposits have been found in the Uluguru Mountains, west of Dar-es-Salaam, just south of Zanzibar, some 100 miles west of the coast. The mica is stated to be of very good quality, and notwithstanding the distance, might possibly show a profit with the excessively low cost of labor existing there.

Philippine Islands.—Mica deposits are reported but have not been exploited.

Australia.—South and West Australia were fairly steady producers of mica on a small scale from about 1890 until 1900, when the exports gradually fell away and finally ceased. Practically all this product was exported to London. The maximum annual production for both provinces was $12,650 in 1894.

New Zealand.—Mica was discovered near Paringa in 1898, but has not been worked.

No doubt numerous other commercial deposits are known to exist, and the above list does not pretend to be complete. It will be observed, however, that only two countries, India and the United States, have been steady producers of granitic mica for any length of time, the former being by far the largest. None of the others seems to offer any great prospects of a steady supply. The immense superiority and ease of working of the Indian deposits taken in conjunction with the low labor cost form a combination which render competition elsewhere all but fruitless.

MAGNESIAN MICAS.

This class of micas has been found in a number of places, as for instance in several localities in New York and New Jersey, and in many foreign countries, in Sweden, Finland, Switzer-

land and Ceylon; but the only known commercial deposits are those of the Laurentian formation in Canada and Northern New York. In this comparative rarity they show a marked contrast to the granitic micas.

The important deposits of this mica are found in a belt beginning in Frontenac county, Ontario, at the northeastern corner of Lake Ontario, and extending northwardly and slightly eastwardly through Addington, Lanark and Carleton counties to Ottawa in Ontario; and thence northwardly in Ottawa county, Quebec, to an unknown limit. In this latter county, most of the best mines are found in the twenty-mile strip lying between the Gatineau and Lievre Rivers. There are also deposits of value to the west of this, running into Pontiac county, and in Ontario west of Carleton in Renfrew county. The formation in the counties named is partly overlain by Cambrian and Silurian rocks, running through Addington county and across the northern portion of Lanark and the southern portion of Carleton counties and also for some miles on both sides of the Ottawa River.

The original source of mica is Ottawa county, Quebec, where it was mined as a secondary product of phosphate mining. When the phosphate mining declined, as a result of the United States tariff and the new phosphate fields of Florida, the mica took its place. As previously explained, mica and apatite are found together in many if not most of the deposits.

The largest mine in Ottawa county is that of Blackburn Bros., near Perkins' Mills, about fifteen miles from Ottawa. It had been exploited on a large scale, with a large force of men, and steam drills, stores, etc., for phosphate before 1888, but in addition to the phosphate an abundance of amber mica was found of excellent quality. There was an open pit 300 feet by 200 feet in area and 130 feet deep; and thence a large lateral drift some 250 feet in length. In developing the mine for mica, the shaft was driven 200 feet below the previous level, but this was subsequently filled in. The mine was provided in 1900 with a seven-horse power hoisting engine and a seven-drill compressor, and eighty-five men were employed.

Another large mine near Perkins Mills is that of Wallingford Bros., which has been worked with fair regularity since 1892, and has reached some 170 feet in depth. The mica is of

fine quality, and drawn from a vein of pyroxene and feldspar about ten feet wide and having a vertical dip. There are two pits side by side, having a total surface area of about 325 by 75 feet, and cross-cuts from the bottom of the smaller pit to another parallel deposit, the outcrop of which appears on the southern side of the shaft.

Other important mines in Ottawa county are those of Fortin and Gravel, west of the Gatineau, a few miles from Ottawa; the Cascades mine on the same side, about fifteen miles north of Ottawa; the Nelly and Blanche mine and the Vavassour mine some nine miles from Ottawa, east of the Gatineau; the St. Antoine mine, formerly the Morin mine, north of Gracefield on the Gatineau (there are a number of unworked deposits of excellent quality in this neighborhood) and the Glen Almond and Allen mines, east of the Lievre River, about fifteen miles above Buckingham.

The mines of Ontario were not developed until some years later, but there is every indication that Ontario will shortly equal or exceed the production of Quebec. The deposits in this province contain mica of unsurpassed quality. In Frontenac county, at the very southern termination of the Ontario mica belt, near Sydenham, is located the Lacey (originally Smith & Lacey) mine, undoubtedly one of the most remarkable mica deposits that have ever been opened, now owned by the General Electric Company. It is now much the largest producer, and has been opened downward for about 160 feet. This mine is located on the east side of Loughboro Lake, across which the mica is transported to Sydenham on the west side. The lode contains mica in massive volume, apparently in a shoot at the junction of a branch vein some twelve to eighteen feet thick, such that the drifts pass much of the time through solid mica. Immense crystals have been taken from this mine. On my visit there I saw several *in situ* from three to four feet in diameter, and a part of a plate some seven feet long was exhibited in the Company's office. I was informed that a crystal was taken from this mine weighing 30,000 to 40,000 pounds, a quantity which in default of exact figures seems highly incredible; notwithstanding which it could be seen that some crystals might well have a volume of a cubic yard or so, which would

weigh about three tons.* The quality varies from the soft, transparent, yellow-brown to the hard, milky variety, and is for the most part of a high grade and quite free from creases.

There are numerous other mica deposits in Frontenac county, some of which have been operated in a desultory way, and doubtless some of these may compare with the Lacey when properly developed. For such development we shall probably have to await, as in the case of the Lacey, the application of American capital on a large scale.

Next to the Sydenham district the most important producing district of Ontario is that of Perth, in North Burgess township, Lanark county, on the north side of Rideau Lake, this belt extending across the lake into South Burgess township, on the south side. Here is located the Hanlan mine, which has been acquired by the General Electric Company, and is being pushed in a similar manner. The mine is situated about nine miles north of the Canadian Pacific Railway, and now comprises a pit about 100 feet deep following the foot wall of a pyroxene dike, and a drift from the base of this shaft along the foot wall in a northeasterly direction. This mine is also noteworthy for large crystals of an excellent quality, though to a less extent than the Lacey mine. The mica is disseminated over a belt about five to eight feet wide.

Numerous other so-called mines are located in this neighborhood, though none of them are now being operated.

South of Ottawa in Carleton county, are numerous deposits of mica, more particularly in March and Huntley townships, which, like most of the others, are not worked.

IV. HISTORICAL.

Mica as a commercial product has its origin in antiquity. How great an antiquity cannot be said, nor is it of especial importance to us to know. In India it has been mined for many centuries, and used for lanterns and other decorative purposes,

*"One crystal of mica was removed with a length of over nine feet and a breadth of from four to six feet, the quality of which was excellent. Great numbers of smaller sizes occur, and the output generally is of extra large dimensions, the crystals being in great masses, and some of the individuals weighing several tons."—R. W. Ells, Bulletin on Mica, 1904, p. 31.

which in fact have remained as the principal if not the only use for it until the nineteenth century. The *lapis specularis* of Pliny, which was strewn over the arena of the Circus Maximus for decorative effect, is supposed to be a micaceous sand, or the detritus of mica schist. Mica has never, however, been mined in Europe to any important extent, no deposits of value being found there.

India.—In India the mines of the Hazaribagh district of Bengal have been worked for many centuries by the Hindoos. Mica is used on a pretty large scale by native artists, not simply for glazing but for decoration of various kinds, and is a regular staple product. The principal native commercial markets for mica are Patna and Delhi.* Dr. P. Breton, who visited these mines in 1826, found as many as 5,000 people employed in getting out mica, at which time but little was exported to Europe. In 1849 the total output is reported as being over 4000 tons, a figure which hardly deserves credence, when we consider that little of this amount was exported, and particularly as this bears no rational relation to the quantity exported in later years, which, enormous as it is (1858 tons in 1901) is small as compared with this. In 1863 the reported exports of Bengal were about 400 tons; but this is scarcely credible in view of the fact that during later years, 1890 to 1894, when more reliable statistics were at hand, the exports never rose to this figure, although the export industry then was undoubtedly much larger. A. Mervyn Smith estimates that one-half of the total output is at present exported, which makes the above figure for production in 1849 obviously impossible. Government statistics of production, though wide of the exported amounts, vary on the other side of the latter, and though they agree fairly in quantities with the latter, they are on the whole less than, and the values only a small fraction of the exported values. The statistics being then contradictory, it is difficult to fully understand the real extent of the Indian mica industry.

Mining in Madras began to reach considerable production only in the year 1894, since which time a considerable export trade has been developed.

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*The following facts and figures are given on the authority of A. Mervyn Smith, *loc. cit.*

United States.—On this continent mica was mined by one or more of the prehistoric races. The evidence of this is found, first, in the existence of prehistoric pits in the western counties of North Carolina, and second, in the finding of mica specula, consisting of plates of considerable size and very widely distributed over the country, even in the extreme west, in archæological remains—more particularly in the mounds constructed by the Mound-Builders. The commercial exploitation of mica by white men began in the eighteenth century. In 1803 was opened the Ruggles mine, at Grafton, New Hampshire, and this was followed by the opening of a number of other mines in the central and southwestern parts of the same State, and mica mining was for many decades an important industry in New Hampshire. The Ruggles mine alone produced over $8,000,000 worth of mica in the century of its existence, and at one time produced four-fifths of the total requirement of the country.

In 1868, however, mica was discovered in Mitchell and Yancey counties, which lie close to the Tennessee line in Western North Carolina, and cover a portion of the Appalachian plateau, which lies between the parallel chains constituting the Blue Ridge and Smoky Mountains. Between Roan Mountain on the north and Mt. Mitchell on the south—the two highest peaks of this section, and, indeed, of the entire eastern part of the United States—will still be found the best-producing mines in the country. Whether operations for mica really first began here or in Cleveland county, on the southern border of the State, where Hon. Thomas L. Clingman undertook some investigations, is uncertain. It seems that prior to that time the attention of the mountaineers had been called to the possibility of finding something of value in the prehistoric pits of Mitchell county (more particularly the Silvers mine on Crabtree Mountain), by a travelling prospector, who thought that specimens of the rock from this mine looked like silver ore. After some work had been done for silver at this mine, of course without success, it began to be concluded that the only thing of value to be found was mica. This, indeed, is clearly the purpose for which the pits were made, because projecting blocks have been found with the tool-marks around them.

The attention of Mr. Clingman being called to the Silvers mine, he began work there and obtained several hundred

pounds of fine mica. Having been called away from the place, several large blocks of it were left on the ground, one of which was picked up by a passing stock drover and taken to Knoxville, Tennessee, where it was seen by J. G. Heap, of Heap & Clapp, dealers in stoves and tinware, who at once recognized its value, which was in those days many times greater than it is now. The rest of the story of Messrs. Heap & Clapp can best be told in the language of William B. Phillips,* from which the account is principally taken.

"Heap & Clapp first worked the Silvers mine, and by following the old leads obtained large quantities of excellent mica. They cut new trenches, ran an adit in and sank several shafts. They also worked the Buchanan or Clarissa mine, by shaft and adit, and found it equally good. Several other mines were opened and worked, as the Deake and Flat Rock. As local experience was acquired (the *sine qua non* in mica mining, as in every other kind), they extended their operations, so that up to 1882, of the 400,000 pounds obtained, Heap & Clapp must have mined by far the greater part. The average spot value of cut mica then was about $2.00 per pound, some, however, selling as high as $11.00. Even at $2.00 the total value of the mica up to 1882 would be $800,000. As to the profits, no very definite information can now be given."

From the beginning of 1867 or 1868, the mica mining industry rose to a boom in 1869, and rapidly turned to a "fever," which paralleled on a small scale the California gold fever of twenty years previous. People rushed from all parts of the country to the mining districts, and mica prospects were opened in most of the mountain counties of North Carolina. It is a noteworthy fact that the character of the ground changes almost abruptly at the Tennessee boundary, and no mica is found to the west of this line. Mica properties changed hands at fabulous rates, and indeed at $8.00 to $10.00 per pound for cut mica the profits themselves were fabulous, and particularly so for the inhabitants of that part of the country. This lasted for upwards of ten or fifteen years, when a decline began to set in. In the early stages the business was still good, but the price of mica had declined, as it was that time

*Engineering and Mining Journal, April 28, 1888.

(1884) that India mica began to be imported, and the prices of the latter were very much lower than those which had been obtained for the native product. The decline continued and was accelerated by the importation of Canadian mica, which began about 1886, for the latter could also be sold at a much lower price, as it is much more easily mined than the Carolina mica. It seems, moreover, that the excessive cost of large-sized plates had caused the stove makers—then the principal users of mica—to diminish the sizes of their glazing panels, which of course immediately had its effect on the price of the larger sizes, as well as on that of the average price for run of mine. The mica industry remained unprotected against foreign importation until the passage of the McKinley law, in 1890, which placed a duty of 35 per cent. on all imported mica, and thereafter the North Carolina industry revived for a short time, notwithstanding the fact that Indian and Canadian mica continued to be imported in large and ever increasing quantities. It is thought that the increasing demand, due to the rising electrical industry, had at least as much to do with this as the tariff. The Dingley tariff law, which went into effect July 24, 1897, increased the duty on imported mica, making it 20 per cent. *ad valorem* in addition to six cents per pound on trimmed, and twelve on cut mica, the latter having reference to the North Carolina mica.

In the later years some mica mines have been opened in other States, notably in the Black Hills region of South Dakota; but up to the present time these have furnished but a small quota of the total production, though increasing. Mining in New Hampshire has, on the contrary, undergone a slow but steady decline since about 1870, when the North Carolina mines opened. The great Ruggles mine, after supplying mica for nearly a century, was closed on account of litigation about 1898, and I believe it has not since been reopened. At the present time only two or three small mines in New Hampshire are being operated.

Canada.—Canadian mica-mining had its origin as such about 1890, as a sequel to the "phosphate boom" of the eighties, but during the latter period mica had also been mined as a by-product of the output of phosphate rock, since about 1886, when it made its appearance on the market in the United

States. So long as glazing was the only use for mica, the Canadian product, which is unsuited for that purpose, remained valueless, and for several years after it was put on the market, it met with scant notice and appreciation, even for electrical purposes. About 1890-93, however, electrical manufacturers began to realize the fact that there lay at their hand a supply of mica superior in quality for their purposes to the native product, and at a much lower price, and the Canadian mica industry dates its real beginning from that time. The General Electric Company, of Schenectady, N. Y., was among the first to realize this, and has always since continued to be the largest user of Canadian mica. At the same time, owing to new deposits opened in Florida, and the new import duty imposed on phosphate rock, the phosphate industry of Canada petered out, and many of the old dumps were bought up by speculators and ransacked for the mica they contained, which was put on the market in large quantities. The old phosphate mines were reopened and were now worked for mica, so that Canada began to cut an increasingly important figure in the mica market. The principal original source of the mica was Ottawa county, Quebec, and Ontario's quota in the total production was inconsiderable up to about 1895, when its production began to increase and has latterly done so very rapidly owing to the part taken by the General Electric Company, which has since 1901 purchased extensive properties in Frontenac and Lanark counties, Ontario, and more recently also several in Ottawa county as far north as Gracefield, some forty-five miles north of Ottawa.

The entering of the mica-mining field by the General Electric Company is connected with an incident in the industry which deserves mention in this place, and one which had in the end very deleterious results on the profits of the industry. As usually happens in a small, and not infrequently in a large industry, certain operators made an attempt to corner the market for mica, whereby the prices received by producers should be forced down and the prices demanded of consumers forced up. The American Mica Company—the so-called mica trust—was formed in 1900 with a capital of $3,500,000 by a combination of the larger mica dealers, including Eugene Munsell & Company of New York, the American Mica Company of Boston, the W.

H. Sills Mica Company, Chicago, and the Sills-Eddy Company of Canada; and options were secured on most of the other companies so as to control the largest producing mines. It was sought to purchase the bulk of the mica product and hold it in store, whereby a famine should be produced, and the prices should rise owing to increased demand. Apparently, however, the possibilities of this situation had not been fully reckoned on. The General Electric Company, finding its mica supply abbreviated and the future uncertain, determined to secure control of its own supply by purchasing and operating mining properties, thus securing those above mentioned. On the other hand, the abnormal rise in prices produced by the corner, caused a ransacking of old mine dumps, and an opening of new mines, and mica was brought into Ottawa in such quantities that the market was swamped and broken. The natural result followed—a period of prices so low as scarcely to reimburse the producers for the haulage, and many months of depression followed during 1902 and 1903.

In addition to this the producers were themselves, and doubtless still are, under some misapprehension as to the actual state of affairs. The large-sized mica is still being held back, I believe in the hope, if not expectation, that prices will return some day to their former level. Needless to say this expectation will never be realized,—never, at least, until some new use for mica has been discovered, because electrical needs, as aforesaid, are now amply satisfied with small-sized mica. The reasons for the supplanting of continuous sheets by the composite mica-board was not wholly due to the excessive cost of large sheets, but to the fact that the composite product is really a better insulator, as will be explained later.

There can be no doubt, however, that the effect on the industry as a whole, of the action of the General Electric Company must prove a beneficial one, for it is almost the first to have undertaken mica mining on a large scale with plenty of capital, and according to the most approved modern mining methods. These will be explained more fully in the next section.

V. MINING AND MILLING.

Mica as a mining proposition stands in a class by itself, partly because of its different nature, and partly because it has grown up separate and apart from other mining, and progress in the latter has had little influence on the former. Its position is between ore-mining and quarrying. In ore-mining the object is to recover a certain mass of material, and the mechanical condition in which it is taken out is of little or no importance; whereas this condition is of vital importance in the case of mica, whose value depends so much on the perfect mechanical condition of the plates. In quarrying, on the other hand, as for building-stones, slate, etc., the material desired is invariably in massive form, and all that is taken out is utilized. There is no specializing as to direction, it being a simple question of excavation. The mining of mica is somewhat similar to that of non-metallic minerals, such as talc, asbestos, corundum, etc., in some respects, and perhaps has a greater resemblance to that of certain gems than anything else. The mica, instead of being located in a massive plane stratum having a regular strike and dip, follows generally an irregular course, and in the case of the granitic micas, the total mass is so small a proportion of the vein material as to offer strong inducements to what is known as "gophering," or in North Carolina as "hogging," that is to say, excavating from hand to mouth for the purpose of merely getting what is at hand and without reference to any system of development.

Mica, moreover, has until within the past few years, been mined in the most primitive fashion, and to-day the vast bulk of the mining is still so carried on. Almost the only steps in advance beyond prehistoric methods have been the use of metal tools and of explosives; and even the latter improvement is foreign to India mining at the present day.

The prehistoric miners, in order to break up the mica-bearing rock, used, as the evidence appears to show, the well-known fire-breaking method. A large fire was built against the rock, and when the latter was well heated the fire was withdrawn and water thrown against it so as to crack it. Evidences of the use of fire are found in the ancient pits of North Carolina, and no traces of tools are found other than those of stone-hammers,

notwithstanding copper tools from the mines of Lake Superior are known to have had a wide circulation among the Mound-Builders.

In India the task of getting out mica was rendered much easier by the disintegrated nature of the rock, to which, in fact, as well as to the richness of the veins, is to be ascribed the present great development of the industry in that country.

INDIA.

That these prehistoric methods, even to the dispensing with explosives, should still prevail in India is certainly surprising, considering the fact that most of the mines are now worked under European leadership. In Bengal they are worked only during the six dry months of the year, from November to May, this being the season when there is no agricultural work in the fields. The mining of mica is carried on in the crudest way by the farmers of the surrounding country and their families, and alternates with the production of crops, the wet season being unsuited to mining operations, owing to flooding of the mines, as rain descends in heavy torrents. Apparently there is no limit to the quantity of mica contained by the country, and no difficulty in finding mica veins; consequently economy in operating methods is not attempted. Open cuts are made along the outcrops of the dikes where mica is seen in quantity,* and are continued down twenty to thirty feet until the sides have become dangerous. No timbering is used and fatal accidents are of frequent occurrence. The mining tools and methods are of so crude a character that it is not profitable to carry the pits or cuts further down than the depth to which the dike material has been sufficiently disintegrated to make progress easy; and the "hogging" plan, as carried on in North Carolina, is here also the accepted mode of operation. The mining is done by coolies, both men and women, whose wages average three annas (four cents) a day for the men and six pice (two cents) for the women. The former act as miners and the latter take the place of trammers and pumps in a civilized mine, stand-

*The feldspathic gangue is disintegrated by the heavy rains and washed away, leaving the mica-blocks projecting. The spots so found are marked off after the rains for operating during the dry season.

ing or sitting in double line on ladders and in the passages and passing earthen pitchers containing water and baskets containing excavated matter from one to another. The full pitchers and baskets are handed up one line and the empties down the other. In this way it may require as many as seventy women to remove the water from a mine not thirty-five feet in perpendicular depth, though of course the actual line is considerably longer.

The shafts are usually built on an incline and sometimes have a diameter of fifteen to twenty feet, but most are just big enough to allow several pairs of miners to get in and wield their hammers in a cramped position. The tools used consist of a drill, a chisel and a hammer, the drill and chisel being used alternatively and the miners working in pairs, one to hold and one to drive. As no explosives are used it does not pay to carry the operation into the hard rock except where it is very rich, and in this case the ancient fire-breaking method is employed.

Some of the larger mines run to a depth of 100 feet, and a few to even 150 feet in depth. In these cases small vertical ventilating shafts about two feet in diameter are put down to ventilate the inclines, and serve as means for raising the excavated material, for which purpose they are provided with small wooden lifts, called lataps.

In the Hazaribagh district the mines on the Dorunda and Satgawan estates, and those in the Koderma Government Forest Reserve are under Government management, and are leased by the Government at fifty rupees per acre annually, with certain provisions which practically prevent speculation and compel their operation by the lessee. Of the private estate mines, the majority are operated by F. W. Christein & Company, of Tisri, who in 1897 operated 110 mines; the next largest operators were Raj Krishna Sahana (thirty-one mines) and W. R. McDonald (twenty-eight mines) ,both of Koderma.

Work is carried on only in the daytime, from 8 A. M. until dusk. At the end of each day's work the product, which has been brought to the surface, is gathered into bundles, tied with bark-strippings and taken to the manager's bungalow, ready for the trimmers and cutters the next day.

The splitting, trimming and cleaning is done as follows: The

workman sits on the ground before a stout peg, which is driven vertically thereinto, projecting about eighteen inches. He holds a mica block with one side against the peg and opens it with the point of a sickle-shaped knife into slabs about one-eighth of an inch thick. The rough, ragged surface of the plates are then removed with the knife, and they are trimmed around the edges so as to cut away all rough and flawed portions. After trimming, the plates are assorted according to quality and sizes, in four grades of the former and six of the latter, as explained in Section VII. They are then ready for market and are packed in boxes of a hundredweight each and transported on carts to the nearest railway station, varying from thirty to one hundred miles in Bengal. All the product of Bengal goes to Calcutta for export.

The above description relates particularly to the Bengal mining; that of Madras is somewhat more modern owing to its more recent development, but the waste in either case is excessive. The mica mines of Nellore are on government property and are exploited on a lease from the government in a similar manner to those of Bengal.

UNITED STATES.

Mica-mining in New Hampshire and that in North Carolina have from the beginning taken different directions; the method employed in the former State being mostly by open trench, whereas in the latter the shaft-and-tunnel method is that in general use. Until recently hand-drilling only was employed in both districts; but in 1897 Albert J. Hoskins, a large New Hampshire operator, introduced steam drills at his Grafton Center mine, and demonstrated to his own satisfaction that it caused a reduction of 50 per cent. in the cost of mining. Had it not been for the general decline in the industry, there is no doubt that this would have resulted in a general introduction of power-drills. Compressed-air-drills have been introduced in the Alstead district (Cheshire county), and the Davis mine, which is thus operated, turned out the first year 600 tons of scrap and a large amount of sheet, and was reported as being one of the best paying mines of the State.

The great bulk of the mica output of this country is and has

been for many years produced in the State of North Carolina. All the mines in North Carolina, however, strange to say, have stuck to the ancient method of drill-bit and hammer, operated by two men in a gang, one to hold and one to drive. It has been frequqently stated that the North Carolina lode could not be mined with steam drills profitably, because of the amount of good mica which would be spoiled thereby. The theory was that the steam drill would, in drilling the hole, keep right on through quartz and mica alike without discrimination; whereas, by the hand-bit method, one always knows by the yielding of the drill when a mica crystal has been struck. The naive quality of this argument will doubtless seem amusing to those who have used the steam drill in mica mining, as in New Hampshire; but can hardly have much force for anybody who lives north of the Mason and Dixon's line. Although no doubt this contention has a basis of fact, and more care is required with a power-drill than would be with a hand-drill to avoid unnecessary destruction of mica, yet it is undoubtedly for the most part a fiction based on the miner's (particularly the North Carolina miner's) prejudice against anything that is new, and on the fear lest the introduction of power would take away from his earnings, when as a matter of fact there is very good ground for the assertion that it is the only thing which can save the industry in North Carolina. Power drilling has been tried in North Carolina and been pronounced a failure, but there is good reason to suspect the *bona fides* of this trial. When it is understood that the average rate of drilling in North Carolina for two men is about twelve feet a day, whereas a good steam or air drill will do the same work in about two hours, it will be readily seen where the economy comes in, even with labor at $1.00 a day.

There is another theory of those interesting people, the miners, which I believe has never been offered any proof in the domain of fact, and that is that the mica becomes poor in quality, or gives out after a certain depth has been reached. Perhaps this may explain the fact that there are few mines of any considerable depth; but more likely the reason for both of these circumstances is that the rock becomes harder (because less disintegrated) as the mine becomes deeper, and therefore less easy to work with a hand-bit and a sledge hammer. A con-

siderable quantity (just how much would be impossible to say) of the North Carolina product is what we may call the result of off-day work. When the mountaineers have nothing else to do, two of them will get together over a hole in the ground and "hog"* it for a few days, bringing out a half dozen good blocks of mica, perhaps, which they carry to town and sell. One way of working a mine is on the royalty plan, the miner paying the owner of the mine a royalty of ten to twenty per cent. of the product taken out. The miner by this plan has little care what becomes of the mine after he gets through with it, so long as he succeeds in extracting the maximum possible value.

The pegmatite dike or vein containing the mica is usually buried under an overburden of soil, which must be removed; or else an adit is made from the side at a more convenient spot, but requiring the removal of some intervening rock. When the mica lead is reached, it is found frequently to follow the wall of the dike, so that the tunnel may be excavated in the softer country rock. If the lead is followed downward, an accumulation of water makes pumping necessary, but where the mine is on the side of a hill drainage can usually be effected with a siphon or cut-drain. The Ray mine, in Yancey county, has been carried under the Toe River, and several successful mines have been carried to 300 or 400 feet in depth where continuous pumping by power is required, but most of the mines have reached their commercial limit at a less depth, not on account of the failure of mica, but because of the cost of pumping. It is just here that power-mining would undoubtedly pay best, by increasing to so great a degree the quantity of product mined in a given time. In the larger mines the drifts are carried fairly straight, but in others they are quite crooked.

Near by a mine which is in operation with a considerable force, a blacksmith is kept with a portable forge for sharpening drills, and usually the mica-dressing shop is also located here, to which the blocks are taken and where they are first split into

*Hogging a mine means in North Carolina parlance to remove only enough of the rock material to follow the string of mica crystals, and as this passes from one side to another, so the tunnel zig-zags about in a crude fashion, which enables the operators to get out the greatest value with the least amount of work for a few days, but of course renders the task of the next comer more difficult and expensive.

slabs one-eighth to three-sixteenths of an inch thick, and afterward they are thrown into a revolving wire-screen of coarse mesh and washed to remove the dirt. They then pass to the cutter or scriber, according to the way the cutting is done. Rectangular wooden templets are kept on hand in a variety of stock-sizes, and the operator selects the templet which his eye tells him will give the largest possible panel of clear mica from the sheet. The scribers, owing to their experience, are paid high wages, as an inexperienced scriber could spoil many times his cost in mica by faulty cutting. The scriber scratches a line around the edge of the plate with a steel point and passes it on to the cutter, who cuts the plate on the marked lines with a large stationary shears like that used by tinners. In smaller operations the plates are not scribed, but the templet is simply held thereon while the shears cuts around it. The mica as so cut is put up in pound packages of each size, and thence shipped to market by team many miles to the railroad. There is generally a store-house for the cut mica at the mine, and if any quantity of the product is on hand, it is necessary to keep a night watchman with a gun to look after it, for mica to the Carolina mountaineer is just like gold to ordinary people, and while apt to be honest in most ways, he will steal it if he gets a chance.

The manner of handling the mining force is of special importance in mica-mining owing to the power for good or evil they possess over the results. If the miner works by the day he will take no particular pains with his work, and may cost the owner several hundred dollars by careless drilling in a single day. For this reason a vigilant foreman is kept to oversee the drilling and blasting, or else the miner is given sufficient interest in the value of his product to insure good results. Many of the mica deposits are let out on the tribute plan for a royalty of one-sixth to one-eighth of the product, but it is still necessary, where any considerable force is employed, for the owner to have an inspector to insure proper working of the mine and proper returns of mica.

While the North Carolina industry cannot be expected to compete with the imported mica for electrical and some other purposes, still, as first-quality glazing mica, its product is unsurpassed, as indicated by the much higher prices paid. But these prices are much lower than those that were paid twenty years

ago, and it is time for the North Carolina people to realize that these prices have come to stay, and to adapt themselves to that fact. While it cannot be expected that the industry will ever again yield the inordinate profit that it once did, there is no doubt that a great improvement could be made by a scientific application of modern machinery on a fairly large scale, and that what yields a miserable pittance to the mountaineer might be made to yield a very fair degree of profit to the mine owner by a judicious investment of capital in this direction.

The New Hampshire industry is distinguished by the large proportion of scrap and of small sizes, because of which a large, if not the largest portion of the sheet is sent to market in the rough-trimmed condition in which it can be used for electrical purposes. There are undoubtedly many good and workable deposits still existing in New Hampshire, which, however, cannot apparently be worked profitably at present prices. It is understood that litigious quarrels have had a good deal to do with shutting down some of the mines, but it remains true that the industry can show little profit in this State at the present time. The cause is to be sought not in the decline in quality of the mica, or the exhaustion of the mines which once produced so plentifully, but simply in the decline in price. It can readily be understood that mines which would show immense profits when small panels of mica were sold at $8.00 per pound, will not pay to work when the finest cut mica can be obtained at about one-tenth that figure.

CANADA.

In Canada there is a better outlook for modern mining methods than anywhere else in the world at the present time. But even here they have been introduced only on a baker's half-dozen of the best properties. Power-drills were employed back in the eighties in mining the phosphate in the larger mines of Quebec and Ontario, and this method was naturally continued when mica was exploited on the same properties. At the Blackburn mine previously referred to there is a seventy-horse-power hoisting engine, a well-equipped hoisting outfit, and a seven-drill compressor plant. The General Electric properties, in Ontario, however, are the very best examples of modern mica mining, more especially the Lacey mine near Sydenham.

The Lacey mine is located on a rich shoot of mica through which a vertical shaft has been driven about 160 feet deep, which, when I visited the mine, in 1903, served nine levels, and most of the stoping had been done to the south and west of the shaft. The shaft is vertical, about eight feet in diameter, and covered. It is provided with a hoisting-bucket, which as it

Fig. 24. Villeneuve mine, Ottawa Co., Quebec. Muscovite. The boundary between the white pegmatite, and the dark country rock (gneiss) is apparent on the left. The dike is 140 ft. thick. Mined for white mica, feldspar and quartz. Abounds in gems and rare minerals.

reaches the top is carried out at one side and deposits its contents either on a tramcar which delivers it to the dump, or direct to the sorting shop, according to the nature of the material. Ladders are provided around the hoistway for the ascent and descent of persons. The levels did not for the most part extend very far from the shaft, and, as might be inferred from the

nature of the deposit, they formed chambers rather than tunnels, irregular in position, direction and size. Up to the time of its purchase by the present owner, the mine was not worked regularly or systematically, and notwithstanding its incomparable richness, can hardly be said to have made a financial success. The General Electric Company, on acquiring the property, improved the existing workings as far as possible, and plans were made of the different levels, a six-drill compressor plant was installed, and a still further and important new departure has been undertaken in the application of the diamond drill for making test borings, whereby the position and quality of the lode is ascertained. Mica-mining at this mine approaches more nearly the condition of advanced ore-mining than in any other mine in the world. The Hanlan mine, at Perth, Ontario, referred to on a preceding page, is owned by the same company and has been similarly developed, and several others in Ontario and Quebec are in process of development. Power-drills will undoubtedly be employed in all its mines, as it believes that the cheapest and most profitable way to exploit a mica mine is a systematic and orderly way. The ultimate result of this example may be to revolutionize the Canadian industry.

In all the smaller mines mica-mining is still carried on by hand-drilling and blasting, with a horse derrick or whin over the deeper holes to raise the excavated material. The work is carried on fitfully. In summer time most of the mines are idle, this occupation being here, as in India, a sort of spare-time occupation for the *habitants*, carried on when there is no harvest or field-work going on. During the winter, however, the mines become crowded, and on the large properties day- and night-shifts are run. This season is also preferable for the transportation of the mica, it being both easier and less destructive to transport it in sledges or drags on the snow than in carts. As nearly all the mines are a long distance from railways, this is an item of considerable importance. The only mines running a day- and night-shift the year around are those of the General Electric Company.

Although the mica district of Ontario and Quebec is dotted with so-called mica mines, the greater number of them would hardly be recognized as such by one accustomed

to seeing the great or even the little mines of the United States, and the same is equally true of the "mines" of other minerals of Ontario, of which there are a great number and variety. They are little more than prospect holes, pits varying from a few feet to perhaps thirty or forty feet, with no lateral drifts or tunnels of consequence. The district abounds in openings, in fact it seems possible to locate mica deposits with the greatest ease, so numerous are they, but they are little worked, the principal object of the owners of these holes being apparently to sell them to someone else. During the busy season of the year about 500 to 700 men are employed in the Canadian mica mines, a much smaller number than in India, though the total output is by no means so disproportionate. In 1898 a little over two-thirds of the total output was from Quebec, but at the present time the production of Quebec and Ontario is about equal.

The method of preparing mica for market in Canada is about the same as in India. After each blast the mica blocks are separated from adhering rock and those which appear of value are sent to the trimming-shop where they are split to about one-eighth of an inch thick, and the worthless pieces are thrown away. The remainder are rough-cobbed according to size before trimming them, worthless pieces being broken off by the hand, and cracked plates being broken in two. This is done at the mine. The grades are according to the largest rectangular panel if clear mica which can be cut from a plate. Of course it requires some little experience to sort the mica by the eye only. The foreman receives $2.00 to $3.00 a day and the workmen thirty cents to $1.00 according to the value of their services. This work is largely done by boys. Mica while being sorted is placed on sorting tables and thrown into bins from which it is taken and packed into barrels, such barrels holding from 350 to 400 pounds, and they are marked and weighed before leaving the mine. They are then shipped to the cutting factories, most of which are located at Ottawa. On reaching the cutting factory the mica is again overhauled and undergoes several resorting, splitting, trimming and cutting operations, each piece passing through a succession of hands. They are first more carefully sorted than at the mine, split to a thinness not exceeding one-sixteenth inch, and after grading according to quality,

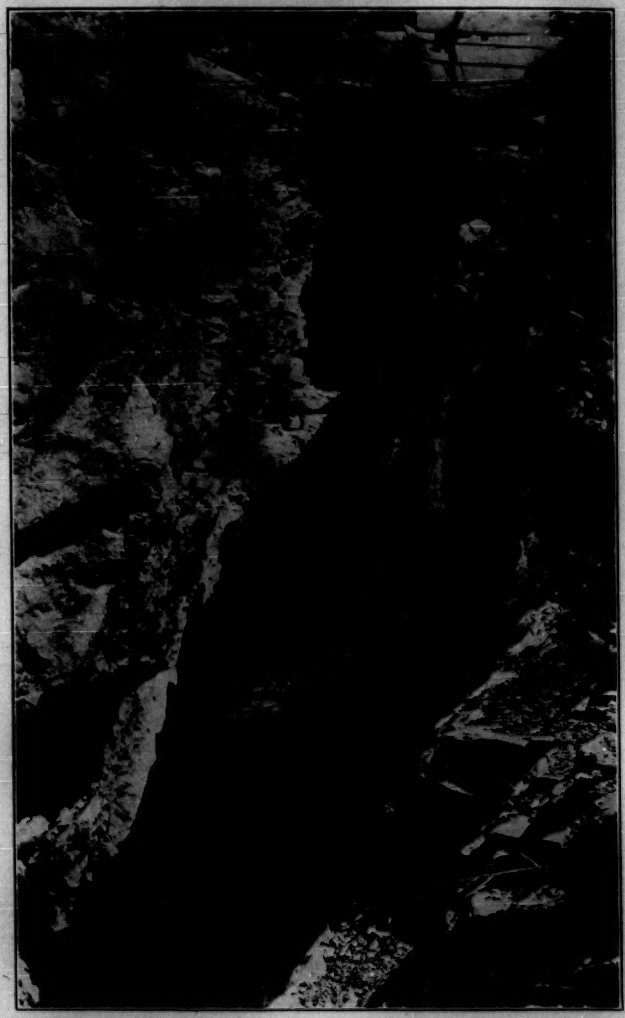


Fig. 25. Little Rapids mine, Ottawa Co., Quebec. Amber mica with apatite and pyroxene. Mined for mica and apatite at intervals since 1892.

passed to the cutters, who trim each piece around the edges with a shear in any shape that it will take to free it from flaws. The cutting shear used for this purpose is stationary, similar to that used in North Carolina. In the General Electric factory at Ottawa, where about sixty to eighty girls are employed, all the shears are worked by over-head shafting, and it is only necessary to hold the pieces up to the shears. After being cut, the mica is again graded and sized, and after it is in proper condition it is sent to the fine-splitting tables, which are located on the second floor in the factory mentioned, the remaining work being done on the ground floor. This last process is done without the aid of machinery, and consists merely in splitting the mica sheets by means of a special knife into laminæ of less than a hundredth of an inch in thickness, cleaning out thoroughly all inclusions and dirt, and casting away all imperfect plates. This is done only with the mica used for the purpose of making the compound insulator called micanite, described below. For mica destined for the open market this last process is omitted.

Originally the mica of Canada was treated after the fashion of North Carolina mica, being cut into square panels at the mines; but this process was soon dispensed with, as it was not adapted to electric mica, the necessary forms being of so irregular a character that much mica was wasted, in addition to the extra labor of cutting. The mica was then marketed as knife-trimmed, and this lasted until the beginning of the United States tariff of 1897, which placed an extra specific duty of six cents per pound on "cut or trimmed" mica. This extra duty was at first held to apply to knife-trimmed, but not thumb-trimmed mica, so that for two years no knife-trimmed mica was imported, the whole product reaching the market in *thumb-trimmed* condition, which of course needed the transportation of large quantities of worthless material, but still proved cheaper than the payment of the additional six cents per pound. This was changed again about 1900 by a change of view of the United States Treasury Department, which for some reason decided to place knife-trimmed as well as thumb-trimmed mica under the "unmanufactured" clause of the tariff instead of under the "cut or trimmed" section, as explained in Section VII, whereupon the knife-trimmed mica again began to be im-

ported and has now for the most part replaced the thumb-trimmed mica.

Even the split, cleaned and cut mica for mica-board is now classed as "unmanufactured" mica, so that the only mica coming under the "cut or trimmed" clause is apparently that cut into special shapes or panels.*

Most of the New Hampshire mica goes to Boston for manufacture, some of it, especially the scrap, being shipped to New York for grinding. The bulk of the North Carolina product goes to New York, the remainder to Chicago and to points in Ohio, Michigan and Indiana. The South Dakota product is divided between St. Louis and Chicago.

An important question, for the solution of which there is little or no information at hand, is the question of costs and profits in mining. These vary so widely in the different countries, in different districts, and even in different mines of the same district, that it would be impossible to give any figures which would represent a useful average. The total proportion of mica to material excavated varies from about ten per cent. to one-tenth of one per cent. in North Carolina, according to J. A. Holmes. In India, according to A. Mervyn Smith, it may average thirty-three per cent., while in Canada in some of the richest mines it may run as high as fifty to sixty per cent. The cost of mining per ton is equally variable, averaging perhaps in the neighborhood of $1.00 for many of the North Carolina dikes, and being less in proportion as the quantity of mica per ton is greater; in Canada it is undoubtedly less than this, and in India presumably only a few cents.

Of the total mica mined an indefinitely small proportion is utilizable as sheet—some two to five per cent. as a rule, according to J. A. Holmes, in North Carolina, but undoubtedly considerably in excess of this in some good mica mines, whereas in some mines in New Hampshire it is all reckoned as scrap. Good Canadian mines probably average about ten per cent. in the knife-trimmed form of merchantable product, which is of course all sheet.

*Just how, why, or by what logical process the "cut or trimmed" clause of the law, which seems explicit enough, has been explained away and whittled down in this fashion is a mystery perhaps worthy the attention of some enterprsing political investigator.

Taking as an example a North Carolina mine averaging one per cent. of crude mica and five per cent. of this as sheet, we would have a total product of one pound of mica per ton, which if it averages a dollar a pound, would roughly approximate the cost of mining. In addition there would be available nineteen pounds of scrap, whose value might run from ten to twenty-five cents.

Manufacture of Mica Board.

In the early state of the electrical industry it was customary to use mica sheets as a whole for the commutators of dynamo machines, this being then almost the only electrical use of commercial importance. It required some years before manufacturers acquired the art of using it for various insulating forms and of combining small sheets of mica into a large and continuous sheet so as to obtain a satisfactory result. Mica board or "micanite," as it was originally termed, was developed by Messrs. C. W. Jefferson and A. H. S. Dyer, in 1892, and they showed that the product when properly made, in addition to being much cheaper than large mica sheets, was also superior to them. It should be remembered that thick plates or slabs of natural mica, such as are used in commutators, are open to several serious objections, the most important of which is the presence of inclusions of foreign matter, which not only destroy in places the continuity of the sheets, but also form, as in the case of rutile and iron oxide specks, paths of short-circuit forming weak points and diminishing the resistance-power of the plate as a whole. Moreover, the plates themselves in their natural state have a polarity developing itself in cleavage planes, that is, lines of weakness along which a crack may be expected; they are apt to be of uneven thickness; and they have little cohesion and are apt to fall apart where not secured together under pressure. In mica board, which is built up of thin separate foliæ, split and cleaned in the manner above mentioned, these defects are eliminated. A surface, as of papèr, having the size of a finished sheet of micanite, is coated with shellac, and the thin foliæ are laid thereon so as to cover it in a single layer as nearly as possible. These of course stick to the shellac, and another coat is laid on over them, followed by another layer of mica foliæ so placed as to cover up the

interspaces between the foliæ of the first layer. This process is continued until the sheet is built up to any required thickness, then the whole is subjected to a pressure of 2,000 pounds per square inch, with simultaneous baking by steam heat. The resulting product is *known* to be of uniform quality and free from flaws; but in addition to this, it is of absolutely uniform thickness, and if properly baked will not absorb water, as mica-plates always do wherever there is a slight opening between sheets, giving admission to damp air. It can be easily sawed, cut and drilled, and leaves clean edges. It has no polarity which makes it more easily cut or bent in one direction than in another. Finally, this compound product is cheaper than natural mica, and has therefore superseded it entirely for large-size work, and even for most of that of ordinary size.

In small establishments, the pieces of mica in the manufacture of board are laid on by hand, but in its manufacture on a large scale, this is done by machinery, so that one girl can make a cubic foot in an hour, the work of twenty girls by the hand process.

The manufacture of tubes, cones, rings and various other forms is carried on in a way similar to the above.

Mica Mat Weaving.

This is an art which has been developed principally by the Mica Boiler Covering Company, Ltd., a Canadian-English corporation having its headquarters at Toronto and its factory at Montreal. The mica used for this purpose is scrap mica. Thin leaves of mica are woven together with wire to form mats, whose principal use is as a thermal insulator for covering boilers, and as a protection against fire. The mica is crimped or fluted so as to leave numerous minute air spaces between the sheets. It is not believed that mica itself has a high heat-insulating quality; but taken in a large number of separated sheets, it may easily become so. Conduction of any importance through such a body is impossible, the mica-leaves alternating with air spaces, and convection must necessarily be slow, while radiation is reduced to a minimum by the numerous reflecting surfaces, as well as by the adiathermanous nature of the mica.

This company employs some fifty workmen at its Montreal

factory and manufactures over a ton of scrap mica per day. The process of manufacture is entirely by machinery, most of which has been patented for the purpose. These machines clean, split and crimp the mica and distribute it to other machines, which weave it into mats. They are used largely on the Canadian railways for boiler-lagging, etc., and on several English railways. The boilers of the new British warship "Drake" are lagged with this product.

A similar product is manufactured in Germany.

Mica Splitting Machines.

But little has been done toward the invention of machinery for the manufacture of mica. In this country patents were issued in 1901 to R. W. Heard and R. A. L. Snyder, of Pittsburgh, for mica splitting machines, these patents being owned by the Mica Machine Company of the same place. In the same year a British patent for such a machine was issued to H. C. Mitchell.*

Manufacture of Ground Mica.

In 1870 a patent was issued to Frederick Beck for a process of coating wall-paper with a mixture of ground mica and transparent varnish. When so applied to a surface, the mica has a luster and sparkle which is not only equal to that of metal, but has the vast additional advantage that its luster can never fade or tarnish with age, as all metals must do sooner or later. Moreover, the great cheapness of the mica powder or flour compared with that of metal caused it to supersede the latter entirely as an ingredient of wall-paper decoration, processes for tinting and bronzing it having been invented. At the present time almost all of the cheaper wall-papers are decorated with large quantities of mica paints, while the finer-tinted grades are used even in the higher-priced papers.

It was not until twenty years subsequent to the invention, however, that the Beck patent began to be utilized on any considerable scale. Small quantities of coarsly ground mica were

*Heard and Snyder's patents Nos. 686,929 and 686,930, issued November 19, 1901; Mitchell's British patent, No. 4969, dated March 8, 1901.

prepared for decorative purposes, such as the production of snow effects on Christmas cards, etc.; but as a staple commodity it has been on the market only since about 1890, and its great development has taken place only within the last few years.

The production of ground mica is not a simple process, nor so easy as might be supposed. In the first place only white mica scrap is utilized, that which is tinged being deficient in luster, and the leaves must be free from rust and specks. The plates must first be beaten up and separated by an opening machine, and divided into comparatively small pieces before they pass to the grinders. Great difficulty was long experienced in grinding, by reason of the soapy or greasy character of the mineral, the plates whereof having a tendency to slide over one another instead of being turned edgewise between the millstones, so that they continued indefinitely without becoming broken up. Both flat and conical millstones have been used with some success, and the grinding is always done with water, but the details of the processes used by the several manufacturers are strongly guarded as a trade secret. After grinding, the ground product requires to be dried, which is a long and rather expensive process as usually carried out.

For the first years of the industry since 1890, a few mills controlled the entire output of mica-flour, the largest of which was the Richmond Mica Company, of Richmond, Virginia. This company attempted in 1897-8 to gain control of the market for mica-flour by buying up the entire scrap-mica output, and thus forcing competitors out of the market for want of raw material. This attempt, however, suffered the usual fate of corners. The price of mica scrap, normally about $7.00 per ton, was run up to $17.00 (according to the "Mineral Industry," or $12,00 according to a native miner), and the finished product was held down; but the artificial market thus created soon collapsed. While it is impossible to suppose that the corner could have lasted very long, the collapse was apparently brought about by the refusal of New Hampshire operators to enter the trust. In the same year (1898) the product of the latter State was run up to 2875 tons, the largest in its history. At the same time the price of flour, which started at the handsome figure of $140 to $200 per ton and was during the period of controlled market from $80 to $90 per ton, broke to about $40 per ton, and the in-

cident closed with the retirement from business of the Richmond company.

Mica is ground to different degrees of fineness, from about ten mesh for spangled effects, lubricants, plastics and fireproofing compounds, up to 160 to 200 mesh for the finer grades of wall-paper.

The mica-flour industry has not been developed outside of the United States. Previous to 1890 considerable quantities were made in Canada, which were presumably utilized for fireproof paints, lubricants and mica-cement insulators. The only market for it was the United States, and when this was taken away by the tariffs of 1892 and 1897 the industry quickly expired.

It must be realized that the development of the scrap-mica industry depends largely on transportation facilities; for the cost of the scrap being but a few dollars per ton at most, a few extra dollars per ton for railroad freights make a prohibitive distinction against such scrap as must pay them, and long-distance teaming is practically out of the question. The New Hampshire mines hold a peculiar advantage in this respect, and those that are still in operation are kept on a paying basis solely by the value of the scrap. In North Carolina, scrap can be sold to advantage as a by-product; whereas in South Dakota, India and other distant localities, the freightage alone on scrap-shipments is prohibitive.

VI. USES.

All the mica industry is to be divided into three principal parts, in accordance with the three principal uses of mica; namely, glazing, electric insulation, and decoration as ground mica. While mica is used for a number of other purposes, it is on these three that the mining industry depends for its existence.

The oldest use of mica, not only by savage, but even by civilized nations, is undoubtedly for decoration. The mica specula found in the graves of America's prehistoric races proves this for the former, as the *lapis specularis* of the Romans does for the latter case. And in India we find it devoted for no one knows how many centuries to many such uses. Lanterns are made

from it for the temples and the bridal processions of the wealthier Hindus; artists use it for their paintings; and inlaid work is made from differently-colored sheets in combination. It forms an ingredient in various ornamental objects, such as toys, flowers, etc. It is also used by the Hindus, mixed with starch, in coarsely-powdered form, as a size for cheap cotton cloths, to give them a sheen.

The art of mica glazing was the next use to develop itself, but appears to be of very recent origin,—apparently imported into Europe from the East through Russia, whence the term "muscovy glass." Its value for stoves and furnaces, where glass would crack, has made it an indispensable adjunct of our civilization, and until fifteen years ago this was the principal use for mica in Europe and America. Practically all the sheet product of North Carolina, and the bulk of the remainder produced in the United States, as well as a large portion of the India mica, is consumed by this industry. The manufacture of mica lamp chimneys has also taken on important proportions in the past few years.

The most important use for mica at the present time, however, is in the electrical industries, as an insulator, and their growth has given an enormous impetus to the production of mica during the past fifteen years, as will be seen from the statistics given in the next section.

As an electrical insulator, mica occupies a peculiar and unique position. There is no substitute for it, nor is there ever likely to be, although, of course, other insulators might be used if mica were unobtainable. It is not only one of the best insulators known from the standpoint of resistance to puncture, infusibility and perfect impregnability to moisture (all qualities of great importance in insulators), but has physical qualities—toughness, elasticity, flexibility, and the extremely thin leaves in which it may be obtained—which render it an ideal insulator in hard every-day service, and these qualities are found combined in no other known substance.

While it is suitable for almost all kinds of electrical work, it finds its chief use in the commutators of dynamos for interposing between the segments thereof. Before mica was universally settled on for this purpose, various substances were tried, but with poor success. Only the softer varieties are suitable

for this purpose, because it is necessary that the insulation-plates should wear as fast as the copper and not project above the surface of the latter, which would cause sparking and irregular running. Generally speaking, white mica, although having a somewhat greater dielectric strength, is unsuitable for this purpose, it being too hard; so that the amber mica of Canada and the soft lepidolite of India are used exclusively. Probably good amber mica is superior to any other kind for dynamo commutators and like purposes, as its present higher price, shown by the statistical charts in the next section, will attest; and it is now being increasingly exported to Europe, which leads to the supposition that there also it has come to replace India mica, which was once used exclusively on the Continent.

Mica is, moreover, being increasingly used as insulation for armature-wires and bars, that is between the conductors of the armature and the iron core; and as for this purpose mica of great flexibility is desired, white mica is also unsuitable, and the amber mica preferred. Armatures whose conductors are insulated by mica are fire-proof, and may be subjected to tests of a very severe character without injury. Those not conversant with electric machinery will little realize how priceless and even vital to our civilization is this one accomplishment, which is rendered possible only by mica.

Great quantities of small-sheet mica,—what would until recently have been termed scrap,—are used for the production of mica-washers, for insulation in lamp-sockets, fuse-blocks and cut-out boxes, and in many other applications in electrical work. For this use any grade of mica is suitable, provided it be free from flaws, specks and rust.

An important use for sheet mica has sprung up very recently and is beginning to attain surprising dimensions, namely, as a sounding-diaphragm. It has been proposed in several patents for use in telephones; but its use in phonographs is the predominating one. The very best leaves for the purpose must be obtained, regardless of cost, as the quality of sounding produced by the instrument depends upon it. India mica has been settled on as the best, and is used almost exclusively. Though the leaves are but $\frac{1}{5000}$ inch in thickness, a single large firm consumes annually thirty tons of mica—equal to two-

thirds of the entire United States production of 1902. Only a small proportion of that bought can be actually used, on account of the perfection required.

The main use for ground mica, as an ingredient of wall-paper pigments, has been referred to in the preceding section. But in addition to this, it is applicable to a great variety of other purposes. It is very largely used in fireproofing and roofing-compositions—usually coarsely ground. The use of ground mica as a substitute for nitro-glycerine, in explosives, is well known, and preceded its present large use as a decorative. Another extensive use for it is in heavy lubricants, this use being founded on the soapy or greasy quality which it possesses in common with graphite and talc. A lustrous hair-powder is, or has been made from it. In the coarser grades it has its use to produce a spangled or frosted effect in decoration and pictures.

Large quantities of coarsely-ground mica are used as aggregating material in combination with a binder, such as shellac, cement, etc., to form plastic compositions, which are used as electric insulators (such as line-insulators) and for applying to metal handles of articles to prevent the transmission of heat.

In India ground mica is applied to a peculiar use, namely, as medicine—said to be efficacious as a remedy for dysentery. The kind used for this purpose is black mica. We might be inclined to smile at the naiveté of the supposition that mica could have any chemical effect on the animal organism; but it is not so improbable as might be supposed, for black mica would be partially decomposed by the gastric juice, and the iron contained therein would undoubtedly prove effective for some disorders. If lepidolite is also used for this purpose (as appears uncertain) the lithia contained therein would be dissolved out in like manner.

Scrap mica has at least one use, aside from that for grinding, which is becoming of increasing importance. I refer to its use as boiler-lagging and for other heat-insulation, which has been described in the preceding section. In principle this must be supposed to rest rather on the numerous polished surfaces presented for reflection of the heat than upon the actual non-conductivity of the material.

(To be concluded.)

Stated Meeting, held Thursday, January 19, 1905.

Tobacco and Sumac. Microscopically vs. Chemically.

By Chester Ahlum.

[The author describes the results of the microscopical method applied to the identification of tobacco and sumac in vegetable materials used extensively by manufacturers of boiler-cleansing compounds.—The Editor.]

In the compounding of boiler chemicals some manufacturers have been making extensive use of vegetable matter, high in tannin, such as sumac and tobacco. The presence of vegetable matter is easily determined in a chemical analysis, but to determine chemically whether tobacco or sumac is one of the ingredients, is difficult and too extended, therefore impracticable in a commercial laboratory where time is a factor.

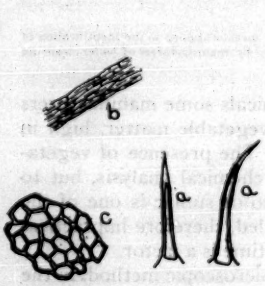
I secured excellent results, by the microscopic method, in the determination of these substances and this method is now being used exclusively in the analytical department of Geo. W. Lord Company. It is much simpler than a chemical analysis and more dependence can be placed upon it.

The process is as follows: If the compound contains soda, or its compounds dissolve in water and bring to a boil, filter off and wash the vegetable matter thoroughly with water, puncture the filter and wash with the least quantity of water possible, into a strong bleaching-powder solution. After the fibre has become bleached wash thoroughly with water and place in a 35 per cent. solution of alcohol. After remaining in this solution about five minutes transfer to 35 per cent. alcoholic Grenacher's Borax Carmine stain, letting it remain until sufficiently stained (about fifteen minutes). Remove, wash with 35 per cent. alcohol and transfer to a weak solution of Iodin Green. In a few minutes remove, wash with absolute alcohol and place in oil of cedar.

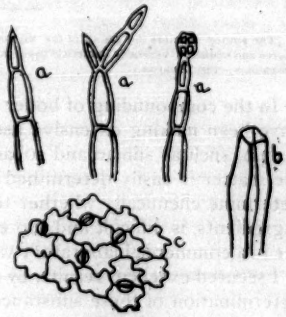
The fiber can be examined in the ordinary way under low power, and if desired may be mounted.

If the fiber is found too small to be handled and in a powdery condition, it may be fixed to the slide by means of collodion fixative. After being bleached, filter, wash thoroughly and fix to the slide by means mentioned above.

Characteristics: Tobacco (Nicotiana Tobacum) is not used in its entirety in the manufacture of compounds, but the rib or stem, presumably because of their small commercial value. Owing to the fact that the stems are almost entirely fibro-vas-



SUMAC
a a—Trichomes or hairs
b—Stem fibre
c—Leaf cells



TOBACCO
a a a—Trichomes or hairs
b—Prismatic cell from stem fibre
c—Leaf cells with stomata

cular and the cells are elongated, the distinction is marked. As in all cases of fibro-vascular bundles the iodin green is taken with great avidity.

The leaf fiber is rarely found in cases of this kind, it being almost entirely removed, but when found it is distinguished by the irregular cells and the abundance of stomata. Hairs are met with occasionally, are multicellular and are of three kinds, single, branched, and those having a cluster of cells at the extremity.

Sumac (Rhus) is used in the form of leaves, and is distinguished by the polyhedral cells and the uni-cellular hairs. The fibro-vascular bundles resemble those of tobacco, but the cells are much smaller. Another marked characteristic is that while

tobacco will take borax carmine very readily, sumac does not, but will take the iodin green.

SUMMARY.

Sumac:	*Tobacco:*
Bleaches slowly.	Bleaches quickly.
Takes the iodin green readily.	Takes the iodin green readily.
Takes borax-carmine with difficulty, or not at all.	Takes borax-carmine readily.
Fibro-vascular bundles composed of elongated cells, smaller than the tobacco.	Fibro-vascular bundles composed of large elongated cells.
Leaf fiber, polyhedral.	Leaf fiber, irregular.
Hairs, unicellular.	Hairs, multicellular, single, branched and lobular.

CONTROLLING INDIVIDUAL WATER SUPPLIES ON IRRIGATED LANDS.

In the irrigated sections of this country the land-owners living along one stream are more or less dependent on each other for their respective supplies of water. One person disposed to appropriate more than his share can readily do so by diverting and holding the water, to the detriment of the farms situated farther down the stream. This is the cause of unending disputes, and all the States in the West have laws designed to overcome it. A new and novel gate arrangement has been recently patented to meet this emergency by L. H. Rhead, a resident of Utah, stationed at the Rio Grande reclamation project, where he represents the United States Government. This gate regulates the flow of water at the heads of distributing canals and laterals, and is especially designed where the scarcity and unsatisfactory distribution of water causes trouble among those concerned. The device consists of an iron gate stem, threaded, and two wheels, also threaded to fit the stem. One of the wheels is for the purpose of raising and lowering the gate, and to the other wheel is attached a chain and padlock, by means of which the second and smaller wheel is locked in any position on the stem, and this constitutes the locking device. This is fixed at a point which will give a land-owner all the water he is entitled to, and will permit him to cut the flow off entirely or partially if desirable, but he is unable to increase it to the point of depriving his neighbors of their share. —*Scientific American.*

ARTIFICIAL ABRASIVES.

The U. S. Geological Survey has just published a monograph on this subject from which we extract the following facts:

Carborundum.—The production of carborundum in 1904 amounted to 7,060,380 pounds, an increase of 2,300,490 pounds as compared with the production of 4,759,890 pounds in 1903. This is the largest production in any year since the beginning of the manufacture of this abrasive and illustrates the increasing demand for it. With the exception of one year, 1902, there has been a continual increase from year to year in the production and use of carborundum, and in that year the decrease was due to a scarcity of supplies used in the manufacture of the carborundum.

Crushed Steel.—The production of crushed steel in 1904 amounted to 790,000 pounds, valued at $55,300, which is the greatest production in any year since this abrasive was first put on the market. As compared with the production of 755,000 pounds in 1903 it is an increase of 35,000 pounds. The average value per pound of crushed steel is 7 cents, the price of the different grades varying from 5½ to 10 cents per pound.

Alundum.—The manufacture of artificial corundum from a bauxite, developed to a commercial basis by the Norton Emery Wheel Company of Worcester, Mass., at its plant at Niagara Falls, N. Y., has met with great success. This abrasive, which is known commercially as alundum, is giving most satisfactory results. The greater part of this material produced by the Norton Emery Wheel Company is used by the company itself in the manufacture of its various emery wheels, stones, &c. There is another artificial corundum that is being used as an abrasive, but it is only obatined in small quantity, as it represents a by-product in the Goldschmidt thermit process. At present none of this corundum is made or put on the market in this country, but at the German factories where the Goldschmidt thermit process is employed it is utilized as an abrasive. In 1904, there were 4,024,000 pounds of alundum manufactured, only a small portion of it being put on the market in the crude form. It was sold at an average price of 7 cents per pound.

PAPER COVERING FOR STEEL.

At th recent meeting of the American Society for Testing Materials, Mr. Louis H. Barker, who is connected with the Pennsylvania Railroad, read a paper on "Protection of Iron and Steel Structures by Means of Paper and Paint," which detailed the results of tests that have been carried on since 1893, using paper instead of paint to protect steel structures. Mr. Baker showed a series of bars, half the length of which had been covered with paper and the other half painted in the usual manner. The paper was put on after the bar had been covered with an adhesive substance, the edges of the covering being lapped. In the samples shown the paper was still intact and unbroken, while the painted portion of the bar showed plainly the need of recovering. The results obtained had been highly favorable to the paper. At the Jersey City station of the Pennsylvania Railroad a very considerable use has been made of the paper covering and with entire satisfaction.

THE FRANKLIN INSTITUTE.

Shaw's Lightning Arrester

[*Being the Report of the Franklin Institute, through Its Committee on Science and the Arts, on the Invention of Henry M. Shaw. Sub-Committee, Thos. Spencer, Chairman; Wm. McDevitt, C. C. Heyl.*]

(No. 2297.)

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the Shaw Lightning Arrester, invented by Henry M. Shaw, of New York, reports as follows:

Mr. Shaw has submitted to the Committee for examination U. S. letters patent 724,339, granted to him March 31st, 1903, and also several samples of the commercial form of his apparatus. He has also personally explained to a member of the committee the details of his device, which will be brought out more fully later in the report.

Before describing Mr. Shaw's apparatus in detail, it is thought best to give a short description of the state of the lightning arrester art, and, to a certain extent, its history.

A lightning arrester is a piece of apparatus whose object is to conduct away to the ground the static charges of electricity which may have gathered in an electric conductor, without disturbing the service of the conductor. There are various causes for these charges occurring in electric conductors, but by far the largest number are caused by lightning.

The requisite of a good lightning arrester is that it should perform its work without interfering with the operation of the electric circuit it is supposed to protect; that is, that it should conduct the static charges to the ground without allowing the useful current to follow it.

The simplest apparatus which will theoretically accomplish this consists of two plates of metal so arranged that there is a small interval or air-gap between them, one being connected with the line and the other with the ground. It is easily seen that the air-gap will form sufficient insulation for the low-press-

ure current in the line (usually called dynamic to distinguish it from the static charges), while the static charges will find no difficulty in leaping across the air-gap to the ground.

As static electricity discharges more easily from points, the edges of these plates along the air-gap are usually serrated.

In this form lightning arresters remained for a great many years, their only use being in the protection of telegraph and similar lines, where they were found fully adequate for the purpose.

But on the introduction of higher pressure currents, it was found that the dynamic current was liable to follow the static spark across the air-gap, an arc being formed, which would soon destroy the arrester or short-circuit the system. To overcome this difficulty numerous devices were invented, some purely mechanical.

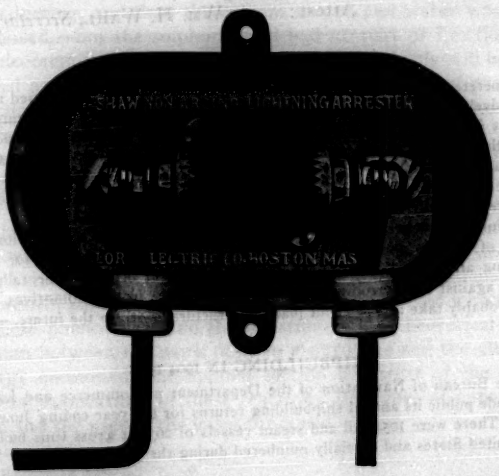
In one an excess of current flowing in the ground circuit caused a magnet to operate a lever, which very much increased the air-gap and so ruptured the arc. As soon as this was done the apparatus returned to its normal condition.

Another depended upon the blowing-out action of a magnet on an arc to rupture it. Still another used the expansion of the air in a closed space caused by the arc itself, to produce the rupture. All these devices were more or less successful. But it was soon discovered that if the air-gap were made up of a series of air-gaps, one after the other, the stepping-stones one might say, being composed of certain metallic alloys usually containing zinc, that a static discharge would easily pass over these steps, but that a dynamic arc would not be formed. Lightning arresters embodying this principle have been constructed in various forms, one of the most common type being a series of short roughened cylinders placed with their axes parallel with a small air-gap between them, the first cylinder being connected to the line and the last to the ground.

Another form is a pile of discs, each disc separated from its neighbor by means of a thin piece of mica. To this class of lightning arresters belongs the apparatus under examination. The drawings and specifications show and describe a piece of apparatus differing slightly in form from the commercial samples submitted by Mr. Shaw, which will be referred to later.

A description of the apparatus is as follows:

Between two brass castings having circular serrated sides, especially prepared high-resistance carbon discs and mica washers are strung alternately on a fibre rod, the whole supported on an insulated base. The brass castings are so constructed that there is a short air-gap between them and the end carbon discs, the serrations on the castings being along this air-gap. The



last point is claimed by the inventor to be important. Although the patent mentions a carbon disc, it does not state that these discs are made of an especially-prepared high-resistance carbon made by introducing foreign substances into the carbon in the course of its manufacture, which is really the case in the sample submitted. This high-resistance feature gives them a great advantage over plain carbon discs when used in a lightning arrester, as their very high resistance makes them act as a sort of insulator and also prevents the formation of an arc, and their conductivity is sufficient to carry without difficulty the static discharges.

The committee therefore conclude that in the main there is nothing very novel in Mr. Shaw's device, but by the introduction of a high-resistance carbon, he has made a valuable improvement and a distinct advance in the lightning arrester art.

As far as the committee can ascertain, the device is original with him, and therefore recommend the award to Henry M. Shaw for his "High Resistance Carbon Lightning-Arrester" of the Edward Longstreth Medal of Merit.

Adopted at the stated meeting of the Committee on Science and the Arts, held January 6, 1905.

Attest: WM. H. WAHL, *Secretary.*

CONCRETE CONSTRUCTION.

Concrete construction has been in use for many years, but is used more extensively now than formerly for foundations, piers and abutments, as well as for bridges. Marked progress was made in concrete construction when the methods of reinforcing concrete with steel were introduced. Concrete arches reinforced with steel ribs or bars, properly designed and constructed, have proved satisfactory for highway as well as railway bridges, and are gradually superseding those of masonry construction.

Reinforced concrete is now used successfully in the construction of floors of bridges and buildings. It has also proven satisfactory for fireproofing and as a protection to the steel work of bridges over railroad tracks against the corroding influence of the gases from locomotives, and will probably take a permanent place in structural work in the future.—*Iron Age.*

SHIPBUILDING IN 1904-1905.

The Bureau of Navigation of the Department of Commerce and Labor has made public its annual shipbuilding returns for the year ending June 30, 1905. There were 1054 sail and steam vessels of 263,064 gross tons built in the United States and officially numbered during the year.

ELECTRICAL SECTION.

(Stated Meeting, held Thursday, December 3, 1903.)

The Electrolysis of Water.*

By Joseph W. Richards.

The title of this discussion may be a misnomer, because, as is well known, the purest water which can be obtained is practically a non-conductor of electricity, and therefore cannot be electrolysed. In elementary lectures on chemistry, perhaps not more than a quarter century ago, the professor explained, when demonstrating the decomposition of water by electricity, that some sulphuric acid was added to the water so as to make *it* conducting, and then the current flowed and water was decomposed,—but the sulphuric acid had no part or function in that decomposition. The explanation may probably still be regarded as about half true; at least, the final result of passing the current is to give us the constituents of water in the proportion in which they exist in water, and so the sum total of all the actions taking place, simple or as complex as we wish to imagine them, is *the decomposition of water*.

We may conveniently divide our subject into its experimental, its theoretical and its applied phases. The experimental part will deal with the conditions under which water is decomposed, and the facts concerning the electrolytic phenomena; the theoretical part will concern itself with the why and wherefore of these phenomena, and the question of the theoretical connection between the work done in electrolysis and the electric energy consumed; the applied section will treat of the commercial applications of these reactions, the types of apparatus used and the uses of the gases produced.

*Review to date.—J. W. R.

I.

The phenomena of the electrolysis of aqueous solutions which yield oxygen and hydrogen, have been studied for a century. The materials which are dissolved in or mixed with pure water in order that the current may be transmitted are usually sulphuric acid, caustic soda or potash, sulphate of sodium or potassium or carbonate of sodium or potassium. Besides these, many oxygen acids and salts, particularly oxygen salts of the alkaline metals, exercise the desired function, and give the desired gaseous products when worked between proper limits of temperature, concentration of solution and current density; outside of these limits, results different from the normal or obtained.

CONSTANTS OF DECOMPOSITION.

The following constants are those most generally accepted:

WATER:	
Molecular weight	18
Specific gravity	1
1 liter weighs	1000 grams.
1 coulomb decomposes	0.093926 m. grams
1 ampere-hour decomposes	0.3351 grams.
OXYGEN:	
Atomic weight	16.
Molecular weight, O^2	32.
Specific gravity (Air = 1)	1.10563
Specific gravity (hydrogen = 1)	16.
1 liter at 0 deg. C. and 760 m. m. pressure weighs	1.4303 grams.
1 gram occupies	699 cub. centimeters.
1 coulomb liberates 0.0829 m.grams =	0.058 cub. centimeters.
1 ampere-hour liberates 0.298 gms. =	207.2 cub. centimeters
HYDROGEN:	
Atomic weight	1
Molecular weight	2
Specific gravity (Air = 1)	0.0696
1 liter at 0 deg. C. and 760 m. m. pressure weighs	0.09 grams.
1 gram occupies	11.11 liters.
1 coulomb sets free 0.01036 m. gms =	0.1150 cub. centimeters.
1 ampere-hour sets free 0.0373 gms. =	414.4 cub. centimeters.

MIXED GASES (detonating gas).	
Specific gravity (Air = 1)..... =	0.4150
1 liter at 0 deg. C. and 760 m. m. pressure weighs.....	0.563 gram.
1 gram equals.....	1.865 liters.
1 Coulomb sets free 0.0933 m. gms. =	0.1725 cub. centimeters.
1 ampere-hour sets free 0.3353 gms. =	621.6 cub. centimeters.

PHENOMENA DURING ELECTROLYSIS.

It is to be assumed that the electrodes used are such as will be permanent, not being attacked by the electrolyte or the products of its decomposition. Such electrodes are not easy to find, because at the anode the tendency is strongly towards oxidation, at the cathode strongly towards reduction. Even carbon (graphite) used as anode seems to suffer some oxidation, platinum is fairly fixed and gold seems to be practically unattacked. A lead anode is at first superficially oxidized to PbO^2, and having reached the limit of its oxidation remains afterwards unaffected. As cathode, gold is recommended strongly by Mr. Carl Hering as being unaffected; platinum slowly blackens, evidently from the superficial formation of a combination with hydrogen and its subsequent decomposition, leaving spongy platinum; lead cathodes blacken and disintegrate superficially, powdered lead falling to the bottom. The action is evidently analogous to that of platinum, but more active. Iron makes a satisfactory cathode in commercial work.

The electrolytes used in the laboratory are usually dilute sulphuric acid or caustic soda. In the case of dilute acid it is imperative to use as anode a material not attacked by the acid alone, and not forming soluble or insoluble sulphate by the action of the current; the cathode may be any material not attacked by the acid alone, and not occluding,dissolving or combining too actively with hydrogen. In the case of caustic alkali, the anode must be insoluble in caustic alkali alone, and not forming soluble or insoluble oxide or hydrate under the action of the current; the cathode may be any material not attacked by caustic alkali alone, strong or dilute, and not forming easily alloys with sodium or the alkaline metals or occluding or dissolving hydrogen gas. In case the cathode can unite easily with sodium or an alkaline metal, we find that it disintegrates rapidly, evidently because of the successive formation of the

alloy and its subsequent decomposition by the water of the electrolyte.

The electrolyte is warmed by the current passing through it, the heating effect being proportional to its resistance as an electric conductor and to the square of the current passing (Ohm's laws as applied to any conductor). The resistance of the electrolytic cell can be calculated from its dimensions and the known resistivity of the solution used, and thus the energy absorbed for any known current, and converted into heat, can be calculated. Or, the cell can be placed in a calorimeter, and the heating effect of the current measured directly; or, the cell itself may be regarded as a calorimeter, the weights and specific heats of electrolyte, electrodes and thermometer obtained, and from the rate at which its temperature begins to rise immediately on starting the current, the number of calories liberated in it per unit of time can be reckoned up. This latter method, though little used, is probably the simplest, easiest and most accurate of the methods proposed.

Energy disappears in the cell in addition to that which re-appears as heating effect such as is calculated or observed above, and the amount thus disappearing is measured by the difference between the total energy expended by the current and the amount of energy appearing as heat. For every watt of electric energy used, the energy expended may be taken as 0.2385 gram calories. If the electrical energy were all converted into heat, the calorimetric effect which would be measured would agree with the above calculation, *i. e.*, 0.2385 gram calories for every watt-second. But investigation and measurement will show the calorimetric effect to correspond to only a fraction of the energy of the current, generally about one-half. A large part of the energy of the current has therefore disappeared in some other function, and that function is the chemical work of liberating the hydrogen and oxygen from water. We are on safe ground when we say that the electric energy thus disappearing in chemical work is exactly equivalent in amount (measured either in thermal or mechanical units of work) to the chemical work done.

The amount of work necessary to split up nine grams of water into eight grams of oxygen gas and one gram of hydrogen gas is, as nearly as is at present known, represented by

34,500 gram calories. An ampere-hour liberates 0.0373 grams of hydrogen, and therefore does an amount of chemical work represented by $0.0373 \times 34{,}500 = 1287$ gram calories. But, a watt-hour of electric energy represents only $0.2385 \times 60 \times 60 = 859$ gram calories, and therefore we need at least $1287 \div 859 = 1.5$ watt-hours to liberate 0.0373 grams of hydrogen. An ampere-hour of current flow can only represent 1.5 watt-hours of electric energy when it falls in potential 1.5 volts; and therefore we have the necessity that a continuous drop of potential of 1.5 volts must be provided for in order to decompose water, that is, for the chemical work of decomposition.

The work absorbed in the decomposition may also be observed in other ways. If the size of the electrodes be taken, their distance apart, and the conductivity of the acid solution used be known, the heating effect of the current in overcoming the ohmic resistance of the bath can be calculated by the well-known formula $\text{Watts} = RA^2$, and thus the heating effect calculated instead of being directly determined calorimetrically. Agreements will be found to be good, if carefully determined in both ways. The total energy of the current employed being $(V \times A)$ Watts, the difference between $(V \times A)$ and RA^2 is the work done in chemical decomposition. This will be found, if carefully determined, to agree closely with the chemical work done, viz., to amount to 34,500 gram calories per gram of hydrogen liberated, or 2.61 gram calories per cubic centimeter of hydrogen gas, or 1287 gram calories per ampere-hour used.

The rate at which decomposition takes place in any given apparatus depends, of course, on the number of amperes passing through it, but this, in its turn, depends on the voltage maintained across the terminals of the bath, although not in a direct proportion. If a voltage of 1.5 is applied, it will be found that practically no current flows, evidently because that much potential is required to start electrolysis and to provide the energy of decomposition. When a slightly higher voltage is applied current begins to flow, but no visible evolution of gas occurs, with ordinary-sized electrodes, until the solution becomes saturated with hydrogen and oxygen gases. With two to three volts liberal evolution of gases usually results.

When the apparatus is placed under pressure more amperes will pass through for the same applied voltage, or the same

number of amperes can be passed through at a smaller applied voltage. If the latter condition prevails, it will be found that the output of gas per ampere-hour is decreased, and also that the calorimetric heating effect in the cell decreases. The cause of these phenomena is that under pressure considerably more hydrogen and oxygen dissolve in the electrolyte, resulting on the one hand in increasing the amount of re-combination of the hydrogen with dissolved oxygen at the cathode and of oxygen with dissolved hydrogen at the anode, and on the other hand in increasing the conductance of the solution and so diminishing its resistance and the consequent heating effect. Whether the amount of gases evolved per watt-hour is increased or diminished I do not know; this field is ripe for considerable experimentation, since no accurate information on the subject has as yet been published.

The amounts of gases liberated and collected in well-designed apparatus are always less than the theoretical amounts, the loss in oxygen being usually greater than that of hydrogen. Losses of both gases caused by re-combination to form water diminish the amounts of each collected, but diminish them in the same proportion as they are being evolved; that is, for example, if recombination is five per cent., then one-twentieth of each gas is being lost. Temporary loss of hydrogen may occur at the beginning of electrolysis by its absorption by the cathode, which, if of palladium, for instance, could absorb 700 times its volume of hydrogen before becoming saturated; but, such absorption has a limit, and after the cathode has absorbed all the hydrogen it can the action must cease, for good, and thenceforth the normal amount of hydrogen be liberated and no more be lost by cathodic absorption. At the anode, oxygen may similarly be lost at first by superficial oxidation of the anode, but this action usually ceases as soon as a continuous coating of oxide is formed. A lead anode, for instance, in dilute sulphuric acid, is quickly coated with brown per-oxide, PbO_2, with consequent disappearance of oxygen, but the oxidation soon ceases, and no more is thereafter so lost.

Another cause of disappearance of oxygen is the formation of hydrogen peroxide or of persulphuric acid or persulphates in the electrolyte. The amounts to which these may form depends primarily on the strength of acid used, temperature of

the electrolyte and the current density used. Elbs and Schönherr* determined the loss of oxygen in the formation of persulphuric acid, at ordinary temperatures, to be:

Specific gravity of sulphuric acid used	Percentage loss of oxygen using current densities per sq. meter of		
	5 amp.	50 amp.	100 amp.
1.15	....	....	7.0
1.20	....	4.4	20.9
1.25	....	29.3	43.5
1.30	1.8	47.2	51.6
1.35	3.9	60.5	71.3
1.40	23.0	67.7	75.7

In commercial practice the strength of acid used and current density are so adjusted as to fall well within the minimum values of above table, but in laboratory tests these conditions may easily be exceeded, and large loss of energy ensue. It should be observed, however, that when the persulphuric acid in solution reaches the cathode, by circulation or diffusion, it is easily reduced by hydrogen or combines with hydrogen to form ordinary sulphuric acid, thus causing an amount of hydrogen to disappear equivalent to the amount of oxygen absorbed or lost in the formation of the persulphuric acid. Variations in temperature have a very great effect on the possible loss of oxygen by formation of persulphuric acid. Under conditions where 32.2 per cent. of the oxygen was so lost, at 27°C, the raising of the temperature to 60°C. reduced this loss to 0.59 per cent. Running the electrolytic cell warm is one of the best means for reducing this source of loss of oxygen, and of hydrogen also.

Loss of oxygen, very similar in its mechanism to loss by formation of persulphuric acid, may result under special conditions from anodic formation of hydrogen peroxide. The condition favorable for its formation, however, is the use of acid over 60 per cent. strong, and this is rarely or never used in commercial practice. If it were, important losses of oxygen, and also of hydrogen, would occur in the formation and subsequent reduction of the peroxide, in a manner exactly analogous to the formation and reduction of persulphuric acid.

A decreased output of oxygen, measured by volume, occurs

*Zeitschrift für Eektrochemie *1*, 417,468; *2*, 162,245 (1895).

most frequently from the formation and liberation of ozone, every two volumes of which is formed from three volumes of oxygen gas, so that for every liter of ozone formed the volume of oxygen appears to diminish half a liter. Conditions favoring the formation of ozone are: increased current density, increased concentration of acid up to fifty per cent., low temperature; working with low-current density, weak acid, and warm solution, the amount of ozone formed is very small. For many practical purposes, the formation of ozone does not impair but rather increases the efficiency of the oxygen gas with which it is mixed, which thus gains in intensity of action more than it loses from reduction of volume.

II.

Concerning the *modus operandi* of the evolution of hydrogen and oxygen gases from dilute sulphuric acid or caustic soda solutions, taken as the most important examples, there are many theories. The oldest is, that the acid or salt makes the water conducting, and it (the water) is then decomposed by the current. Another view is that the acid or salt only is decomposed by the current, and that the water present is attacked by the products of this decomposition and thus chemically decomposed. A third view is that the *mixture* of acid and water, or salt and water, conducts the current, and that this *mixture* is the thing which is decomposed, or resolved by the current, into hydrogen, oxygen and acid or salt. These three views may be expressed by the reactions:

$$2\,H^2O = 2\,H^{+2} + O^{-2}$$

$$2\,H^2SO^4 = 2\,H^{+2} + 2\,SO^4$$

$$2\,SO^4 + 2\,H^2O = 2\,H^2SO^4 + O^{-2}$$

$$4\,NaOH = 4\,Na^{+} + 4\,OH^{-}$$

$$4\,Na + 4\,H^2O = 2\,H^{+2} + 4\,NaOH$$

$$4\,OH = 2\,H^2O + O^{-2}$$

$$\left\{\begin{array}{l} 2\,H^{2+2x}\,S\,O^{4+x} = 2\,H^2 + O^2 + 2\,H^{2x}\,S\,O^{2+x} \\ 2\,Na\,O^{1+x}\,H^{1+x} = 2\,H^2 + O^2 + 2\,Na\,O^x\,H^{2x-1} \end{array}\right.$$

The first theory is untenable, because it is no less logical to speak of the water making sulphuric acid conducting than it is to say that acid makes the water conducting. Pure water is practically a non-conductor, yet a small amount of sulphuric acid mixed with it gives a solution which conducts excellently; pure anhydrous sulphuric acid is practically a non-conductor, yet a small amount of water mixed with it gives a solution which conducts excellently. The only logical and proper conclusion is that the conductivity is a function of the mixing, and that it is the mixture which must be regarded as the conductor of electricity. An analogous case would be the fusibility of silicates of lime. In a blast furnace, pure silica is practically infusible; so is pure lime. Mix them, and the mixture fuses easily in the furnace. No metallurgist says that the lime makes the silica a fusible substance, or that the silica makes the lime a fusible substance; but it is rightly said that the mixture or combination of the two is a fusible substance, and that the fusibility is a property of the mixture only. Likewise to borrow the logical process, the conductivity of aqueous sulphuric acid is a property inherent in and characteristic of the *mixture* and not of either ingredient.

The second theory regards the acid or salt constituent as being the bearer of the electric current, *i. e.*, the conductive constituent of the electrolyte, and as being the constituent primarily decomposed by the current. The first part of this statement is untenable for exactly the same reason as the first theory, which has just been explained at length. If it were allowable or necessary to regard the current as being carried through the electrolyte by the acid or salt constituent alone, then we could acknowledge the force of the corollary, that it alone was primarily decomposed by the current, and that the evolution of hydrogen and oxygen gases was really secondary. But, since the first statement is untenable, the second loses its element of necessity, and must rest upon other grounds of proof or support, if they can be found. The current not being carried by either constituent of the electrolyte alone, but by the electrolyte as a whole, the assumption of the primary and

secondary actions which this second theory requires becomes superfluous and is in fact illogical. Why should the current, after arriving at the electrodes through the medium of the mixed electrolyte, and not through either constituent of it alone, end by decomposing the acid into two constituents which then react upon the water to liberate its constituents? If the current is able to decompose the acid, and the constituents of the acid are able to decompose the water, why not assert at once that the current decomposes the water at the electrodes, and cut out the illogical and unnecessary complication which the theory under discussion involves?

The third theory stands upon the observed fact that only the mixture of acid, or salt, and water conducts; that the *mixture* is, therefore, the conducting body and not either constituent of it; that the current is carried from one electrode to the other as a purely physical operation by the electrolyte or mixture *as a whole*, and not by either of the constituents which united to form it; that, in fact, the constituents of the electrolyte have lost their intrinsic individuality on becoming mixed, having combined with each other or mutually dissolved each other in such manner as to constitute a resultant body or material which contains neither of its ingredients *per se*, but is a compound material which must be considered a unit for the purpose of electric conductivity. This body conducting the current as a whole, from one electrode to the other, the electrochemical action, the chemical decomposition by the electric influence, takes place only at the surface of the electrodes, where the current passes from electrolyte to electrode, and there decomposes the compound body, the electrolyte. In the case of dilute sulphuric acid, the electrolyte contains hydrogen, sulphur and oxygen, in amounts corresponding to a mixture of H^2So^4 and H^2O in some proportion. Calling the electrolyte $H^2SO^4x.H^2O$, we can write this empirically as

$$H^{2+2x}\,S\,O^{4+x}$$

and the electrochemical action is expressable by the formula

$$2H^{2+2x}\,S\,O^{4+x} = 2\,x\,H^{2} + x\,O^{2} + 2\,H^{2}\,S\,O^{4}$$

(+ and − over the H^2 and O^2 terms)

or, perhaps more logically, for the purposes of comparison,

$$H^{2+2x}\,S\,O^{4+x} = 2\,\overset{+}{H^2} + \overset{-}{O^2} + H^{2x}\,S\,O^{2+x}$$

and in caustic soda solution, $NaOH.xH^2O$,

$$4NaO^{1+x}\,H^{1+2x} = 2\,\overset{+}{H^2} + \overset{-}{O^2} + 4\,Na\,O^{2+x}\,H^{2x}$$

On these principles, neither the water nor the acid or salt conduct the current through the bath, but the *mixture* of the two; also, neither the water nor the acid or salt is decomposed, but the *mixture*,—the action of the current being to deprive it (the mixture) of hydrogen and oxygen. These views express more exactly the phenomena, agree more closely with the logic of the situation and the observed facts, and contain no unfounded or unreasonable assumptions.

III.

In Engelhardt's monograph on "Die Elektrolyse des Wassers," he classifies the commercial apparatus used under three heads, according to whether they are used for obtaining oxygen alone, or both oxygen and hydrogen mixed together, or both oxygen and hydrogen separately led off. This classification is, however, a matter of mechanical detail alone, with which we will not concern ourselves.

The real commercial classification is into apparatus with diaphragms and without diaphragms to separate the gaseous products from each other, and further into apparatus with unit couples in multiple and those in series. The multiple or series types have been used according to whether it was desired to work with low or high voltage. Where direct-current electric lighting circuits, of say 110 volts, are available, it is very convenient to have series apparatus adapted to work on those circuits; even when dynamos are installed, it is well to consider that lighting generators of standard voltage are to be found more plentifully on the market, and usually sell at lower prices, than specially-constructed low-voltage machines.

Without further classification we will take up the description of the most successful types of commercial apparatus.

EARLIER FORMS OF APPARATUS.

D'Arsonval, in 1885, was perhaps the first to instal a plant for furnishing oxygen electrically in the laboratory. He used 30

per cent. caustic soda solution as electrolyte, cylindrical sheet-iron electrodes, a current density of two amperes per square decimeter, and enclosed the anode in a woolen bag, to serve as a diaphragm. Only the oxygen was saved. The apparatus used sixty amperes, furnished some 100 to 150 liters of oxygen daily, and was in use several years.

Latchinoff used an asbestos cloth partition, ten per cent. caustic soda solution, iron electrodes, 3.5 amperes per square d.m., and 2.5 volts working tension; or with a five to fifteen per cent. sulphuric acid solution used leads anodes and carbon cathodes. In his first apparatus, the units were all in parallel, but afterwards he used series electrodes, the one side of an electrode acting as an anode and the other as a cathode; a series of forty was used on a normal lighting circuit, with current density of ten amperes per square d.m., and parchment partitions between the electrodes to separate the gases. Latchinoff was also the first to carry out the decomposition under pressure, using a strong iron vessel as electrolyser, and by an ingenious system of floating valves keeping the pressure of the two gases equal in the aparatus. Fig. 1 shows this apparatus, the action of which will be evident from a short inspection.

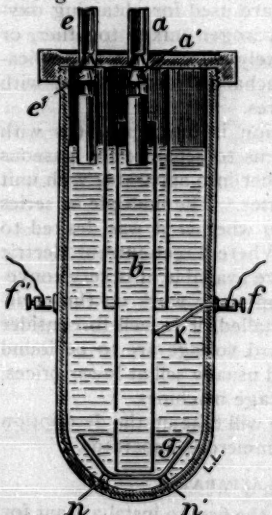


Fig. 1.

Dr. O. Schmidt, in 1899, perfected this series type of apparatus, using bi-polar electrodes, and constructed very practical and workable apparatus in the shape of a filter press, adapted to work directly on 110 volt direct-current lighting circuits. (Fig. 2.)

Each frame in the press contains an iron electrode, which acts as a double-pole (bi-polar) electrode, sheets of asbestos cloth held between the frames acting as partitions, reinforced with rubber on the edges for making tight joints. The electrolyte is ten per cent. solution of potassium carbonate, fill-

ed into the apparatus through the stand-pipe on the right, which communicates with all the compartments through holes in the frames similar to the usual filter-press construction. The gases evolved escape by similar passages into the cylinders on the left end, where they separate from the electrolyte and pass upwards, while the electrolyte, dragged by the gas bubbles, flows downwards back into the apparatus, thus maintaining an efficient circulation. With forty plates, about 2.5 volts is absorbed in each cell, using a current density of about two amperes per square decimeter. The oxygen obtained is 97 per

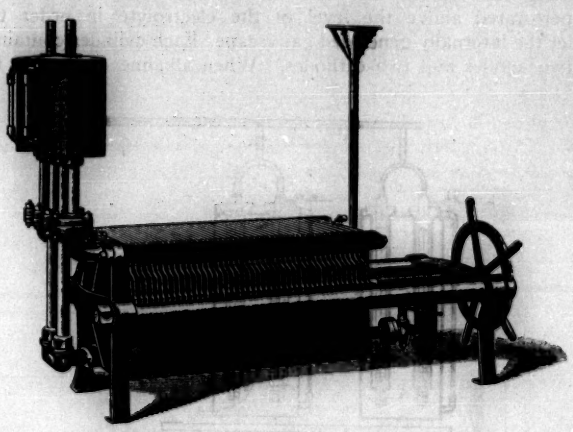


Fig. 2.

cent. pure, which is raised to 99.985, if desired for medical purposes, by passing through a tube filled with platinized asbestos heated to 100 deg. C. Five sizes of aparatus are made, adapted for 15, 30, 60, 100 or 150 amperes, and each may use 25, 40 or 80 frames, for working on 65, 110 or 220 volt circuits. The prices vary from $450 down to $130 per kilowatt of power capacity, according to the size of the machine, and it has been shown that plants in Europe can make good profits when selling compressed oxygen gas at $1 and hydrogen at $0.31 per cubic meter. The Machinen Fabrik Oerlikon in Zurich make

these apparatus, and nearly a score of plants thus equipped are in operation in Europe.

Schoop, in 1900, devised an apparatus with non-conducting and non-porous partitions, which has gone into considerable commercial use. Fig. 3 shows the section of the apparatus, where *a a* are the tubular electrodes of sheet hard-lead, enclosed by glass or clay suspended tubes *c*, which are perforated at their lower ends; the electrode surface is further increased by fine hard-lead or iron wires hung inside the tubular electrodes, the latter being perforated above the level of the electrolyte in order to let the internally-generated gas escape. Each cylinder contains two anodes and two cathodes. When alkaline electrolyte is

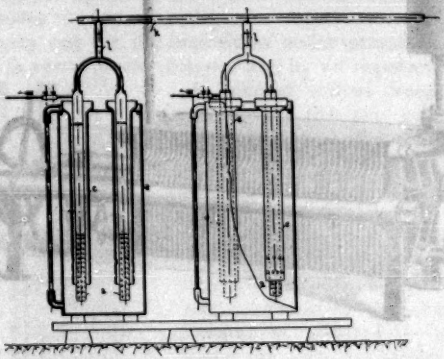


Fig. 3.

used and iron electrodes, the working voltage is 2.25; when sulphuric acid of density 1.235 is used, with hard-lead electrodes, the working voltage is 3.6 to 3.9. The output is given as 68 litres of oxygen and 136 litres of hydrogen per electrical horse-power hour. Fig. 4 shows an experimental plant on this system installed at the Cologne Accumulator works of G. Hagen at Kalk on the Rhine. Only one size of apparatus has so far been made, suitable for 175 amperes and costing $69.25 per unit.

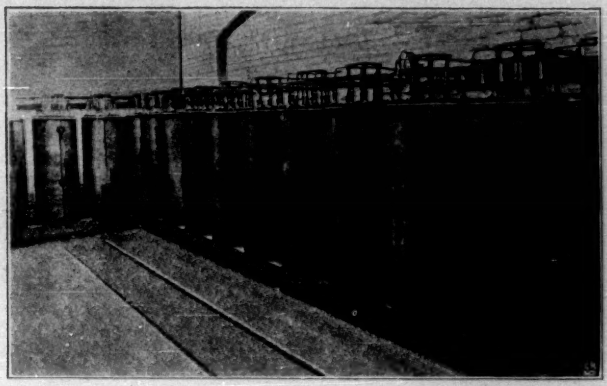


Fig. 4.

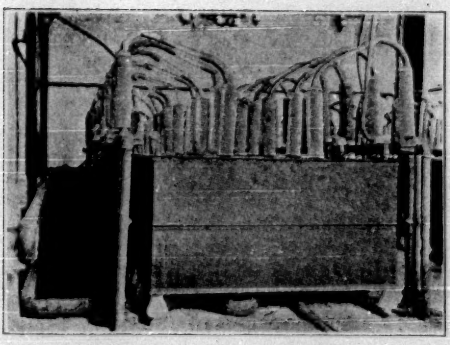


Fig. 6.

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Garuti, in 1892, introduced a new electrolytic principle into these apparatus for the decomposition of water. He uses a nearly complete metallic partition between the electrodes, and avoids the evolution of gases on this partition by keeping the working voltage between the electrodes below three volts. It will be easily understood (now that Garuti has thought of utilizing the principle), that the metallic partition can only act as an intermediate or bi-polar electrode by virtue of the current entering and leaving it; but this would make two decompositions between the original electrodes, necessitating an absorption of $2 \times 1.5 = 3$ volts in decomposition. As long as the working voltage is kept below 3, the partition must act merely as a partition, the same as a non-conducting partition. The advantage gained is in the simplicity and economy of making the partitions of sheet metal instead of burnt clay, rubber, glass, etc.

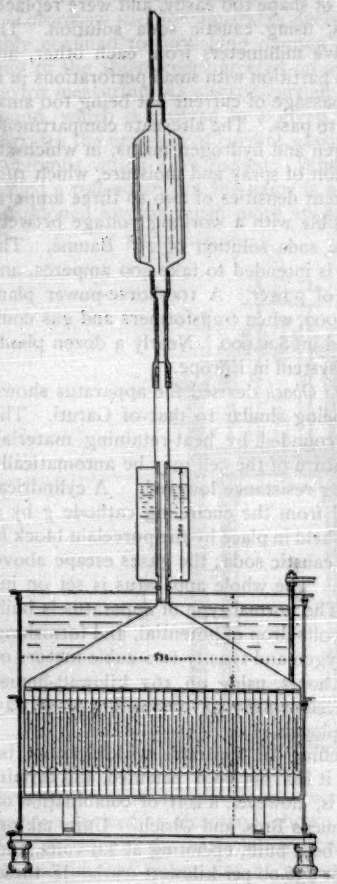


Fig. 5.

Garuti devised many modifications in the de-

tails of his cells, of which Fig 5 may represent the most recent. The original forms made of sheet lead (using dilute sulphuric acid electrolyte) got out of shape too easily, and were replaced by sheet-iron apparatus, using caustic soda solution. The electrodes are only twelve millimeters from each other, and separated by a sheet-iron partition with small perforations in it, the latter allowing free passage of current but being too small to allow any gas bubbles to pass. The alternate compartments are connected with oxygen and hydrogen mains, in which are enlargements for collection of spray and moisture, which runs back into the cell. Current densities of two to three amperes per square d.m. are possible with a working voltage between 2.45 and 3, using caustic soda solution of 21° Baumé. The size cell shown in Fig. 6 is intended to take 400 amperes, and to require one kilowatt of power. A 100-horse-power plant set up at Rome cost $14,000, when transformers and gas compressing plant were added in, $20,000. Nearly a dozen plants are now working on this system in Europe.

Siemens Bros. & Co. and Obach devised the apparatus shown in Fig. 7, the principle being similar to that of Garuti. The cast-iron vessel *a* is surrounded by heat-retaining material, in order that the temperature of the cell may be automatically raised and thus its running resistance lowered. A cylindrical iron anode *f* is separated from the encircling cathode *g* by a cylinder of wire netting *c*, held in place by the porcelain block *k*. The electrolyte is diluted caustic soda; the gases escape above from the spaces n and m. The whole apparatus is set on insulating porcelain feet. The normal type of apparatus is built to take 750 amperes at 3 volts drop of potential, and furnishing eleven cubic meters of oxygen and twenty-two cubic meters of hydrogen per twenty-four hours, using up 162 kilowatt-hours. The cost of this unit is given as $187.50, amounting to $83.25 per kilowatt of current employed.

Schukert & Co. are selling an apparatus which cannot be properly described because it has not been patented, and certain details are kept secret. It is, however, a sort of combination of the ideas of Garuti and Siemens Bros. and Obach. Units taking 200 and 600 amperes have been built, operating at 2.9 volts, and costing only $62.50 each, or $36.00 per kilowatt used. If these figures are correct, it is the cheapest commercial apparatus yet

devised for this purpose; but unfortunately, satisfactory confirmation of these details is lacking.

Laboratory uses for apparatus decomposing water are probably confined to furnishing oxygen and hydrogen, for which any of the above types erected on a small scale, are suitable, or for measuring the electric current. If the volume of gas is found, which is evolved in a given time, the instrument integrates the amperes of current passing; that is, measures the coulombs which have passed. When thus used it has been called a *voltameter*, but the name is a misnomer, and has been abandoned for the much more appropriate term of the oxy-

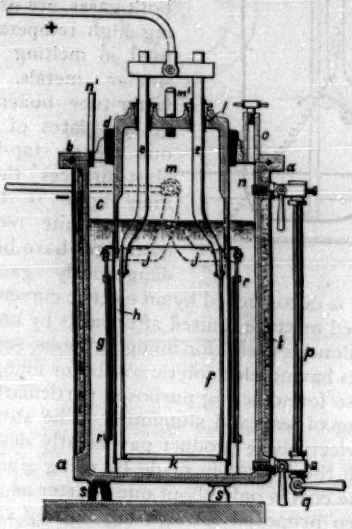
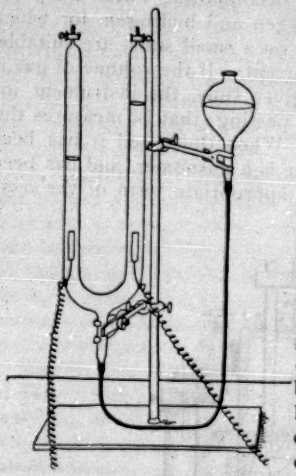


Fig. 7.

hydrogen *coulometer* (coulomb-meter). The laboratory apparatus devised by Hofman is shown in its most recent form in Fig. 8, where the external reservoir enables one to read the volume of either gas at atmospheric pressure. Fig. 9 shows a coulomb-meter for measuring heavier currents, devised by Minet, in which the gases evolved collect in the reser-

voir V and by the pressure which they exert give corresponding indications on the manometer H. The instrument is calibrated by using a constant current passing through a standard ammeter in series, and thus its co-efficient found, the indications being proportional to a constant times the indicated pressure.



The commercial applications of the electrolysis of water are numerous. The mixed gases, or both gases, are useful for obtaining high temperatures, and are used in melting platinum and similar metals, repairing of water-tube boilers, melting together plates of glass, melting out frozen tap-holes of iron blast-furnaces; the Drummond lime light is another application; quite recently blasting cartridges have been devised for dangerously gassy mines, in which water is decomposed by an electric current and the highly compressed mixture ignited afterwards by an electric spark. Hydrogen alone is useful for filling balloons, several European governments having electrolytic plants for filling their military balloons; also for soldering purposes, particularly the autogenous soldering of lead and aluminum. The absence of arsenic makes the electrolytic product particularly desirable, in comparison with the hydrogen made by using zinc and sulphuric acid; also the cost is only about one-quarter as great. Hydrogen has been proposed for lighting railway cars, etc., using very small Welshbach mantles, with resultant advantages in sanitary respects, smaller danger of explosion and smaller piping. Within a distance from the point of production of 180 miles, it has been calculated that the compressed hydrogen is cheaper for this purpose than calcium carbide and acetylene. The uses of oxygen in chemistry, metallurgy, dentistry, medicine, etc., are too well known to need repetition.

In concluding we would refer to a few of the places where further information about the subject treated of in this lecture may be obtained. In the scientific treatment of the subject, we may refer to:

Dr. H. Danneel: Handbuch der Elektrochemie; Specielle Elektrochemie. Lieferung 1. Wilhelm Knapp. Halle. 1903.

S. L. Bigelow: On the passage of a direct current through an electrolytic cell. Journal of **Physical Chemistry, December,** 1902.

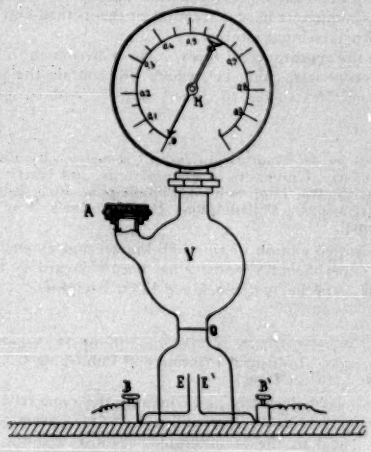


Fig. 9.

C. J. Reed: Gas polarization in lead accumulators. Journal of Physical Chemistry, January, 1901.

J. W. Richards and W. S. Landis: The Electrolysis of Water. Transactions of the American Electrochemical Society, Vol. iii (1903), Vol. iv (1903).

The commercial side of the question has been treated by:

M. N. Schoop: Die Industrielle Elektrolyse des Wassers. 1901.

Engelhardt: The Electrolysis of Water. Translated by J. W. Richards. Chemical Publishing Company, Easton, Pa. 1904.

Various writers: Electrochemical Industry, 1903 and 1904. Particularly December, 1903, page 579.

Book Notices.

The Proceedings of the Chemical and Metallurgical Society of South Africa, with appendix. February, 1897—September, 1899. Vol. II (8vo, pp. xx×928. Johannesburg, Transvaal. Published by the Society. Edinburg: R. W. Hunter. New York: The Engineering and Mining Journal. 1903. (Price, 21s.)

This imposing volume of nearly 1,000 pages, bears excellent testimony to the activity of this society. The subject, which naturally constitutes the theme of many of the published papers, bears more or less directly on the treatment of gold ores, and the extraction of the precious metal, though the volume contains numerous papers treating of theoretical and practical subjects of general professional interest.

The delay in the appearance of this volume is attributed to the disturbing effects of the recent war. Vol. III, which will contain the proceedings of the Society from May, 1902, to June, 1903, is said to be in preparation. W.

Experiments Arranged for Students in General Chemistry. By Edgar F. Smith. Prof. of Chemistry, University of Pennsylvania, and Harry F. Keller, Prof of Chemistry, Central High School, Philadelphia. Fifth Edition, enlarged, with 40 illustrations. Philadelphia: P. Blakiston's Son & Co. 1904. (Price, 60 cents.)

The above entitled edition of this well-known and extensively-used students' guide to experimental chemistry has been enlarged by the addition of a number of new experiments, which add to its usefulness. W.

Western Mill and Smelter Methods of Analysis. Philip H. Argall, B. S., M. A. Denver, Colorado. Industrial Printing and Publishing Co. 1905. Small 8-v , pp. 126. (Price, $1.50.)

This volume describes clearly and consisely the modern chemical methods at present employed in Western mill and smelter operations, and will be found specially useful to the metallurgical chemist wishing to familiarize himself with these methods. W.

Encyclopédie Scientifique des Aide-Mémoires. Librarie Gauthier-Villars, Paris. Small 8-vo. (Price per volume, paper 2 frs, 50c; boards, 3 frs.)

The following-named volumes of this excellent technical series have been issued by the publishers since our last notice. The volumes are sold separately, each being a complete treatise in itself. W.

Nicolardot (P.), Capitaine d'artillerie, Directeur du Laboratorie de Chimie à la Section technique de l'Artillerie. Le Vanadium.

Granderye (L.-M.), Ingénieur Chemiste, Préparateur à l'Université de Nancy. L'Industrié de l'Or.

Stroobant (P.), Atronome à l'Observatorie royal de Belgique, Professeur à l'Université de Bruxelles. Précis d'Astronomie partique.

Martignat (M.), Ingénieur des Arts et Manufactures. Le liège. Ses produits et ses sous-produits.

Jeancard (P.), Ingénieur des Arts et Manufactures, et *Satie* (Conrad), Chef de Laboratorie de la maison Jeancard fils. Abrégé de la Chimie des Parfums.

LeChatelier (H.), Ingénieur en chef des Mines, Professeur à l'Ecole des Mines et au Collège de France. Essais des matériaux hydrauliques.

Granderye (L.-M.), Ingénieur Chimiste, Préparateur à l'Université de Nancy. Détermination des espéces minérales.

Maxwell's Theory and Wireless Telegraphy. Part I. Maxwell's theory and Herzian oscillations. By H. Poincaré. Translated by Frederick K. Vreeland. Part II. The Principles of Wireless Telegraphy. By Fred'k K. Vreeland. 8-vo. pp. xi 255. New York: McGraw Publishing Co. 1904. (Price, $2.00.).

The reader will find this work a most helpful one in arriving at an understanding of the fundamental principles underlying electrical phenomena and their applications in the modern art of wireless telegraphy. W.

Sections.

(Abstracts of Stated Meetings.)

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, October 5th, 8 P. M.

Present, 102 members and visitors. Mr. Charles Day in the chair.

The evening was devoted to the discussion of the subject of Reinforced Concrete in Construction.

Mr. Emil G. Perrot opened the discussion with remarks devoted specially to the use of this form of construction in buildings, and illustrated his remarks very fully with lantern slides. Mr. Walter Loring Webb followed with a paper descriptive of the use of reinforced concrete in the construction of dams. Mr. Webb's remarks were fully illustrated with lantern views.

Mr. James S. Merritt showed a number of lantern photographs illustrating the use of expanded metal in connection with concrete construction, and explained at some length the abuses to which such construction has frequently been subjected without failure, besides bringing out numerous interesting features in connection with building work.

The following gentlemen likewise participated in the discussion: Messrs. J. O. Ellinger (New York),C. A. Hexamer, H. H. Quimby and the chairman.

The chairman announced that the Executive Committee had appointed Mr. Francis Hand as Secretary *pro tem.* to fill the unexpired term of Mr. D. Eppelsheimer, Jr., resigned. Adjourned.

KERN DODGE, Secretary *pro tem.*

ELECTRICAL SECTION.—A *Stated Meeting* of the section was held on Thursday, October 12th, 8 p. m. President Thomas Spencer in the chair.

The paper of the evening was read by Mr. Lawrence Addicks, of Perth Amboy, N. J., on Electrolytic Copper. The subject was discussed by Messrs. Carl Herring and C. J. Reed. Adjourned.

RICHARD L. BINDER, Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Thursday, October 19th, 8 P. M.. Present, 19 members. Dr. Wahl in the chair.

The Chairman introduced Prof. Alex. E. Outerbridge, Jr., who read the paper of the evening on Recent Progress in Metallurgy. The paper was discussed by the chairman and the author, and is reserved for publication. The thanks of the meeting were extended to the speaker and the session was adjourned.

GEO. P. SCHOLL, *Secretary.*

Franklin Institute.

(Proceedings of the Stated Meeting held Wednesday, October 18th, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18th, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 48 members and visitors.

Additions to membership since last report, eight.

The Chairman introduced Mr. E. Stütz, of New York, who gave an interesting and instructive communication on American Thermit Practice. The speaker gave a detailed account of the progress that had been made in this country in the introduction of the Goldschmidt process since the presenation of his paper on the subject before the Institute, some eighteen months ago. Mr. Stütz's paper is reserved for publication.

Mr. Louis Edward Levy presented a description with illustrations of his recent invention, termed an Etch-Powdering Machine. In the process of etching metal plates for printing, the design must be so protected that only the ground is etched away and the design left standing in relief. This has hitherto been done by tedious and troublesome hand process, but is effected automatically with this machine. A series of zinc plates, 15 by 18 inches, a number of line and half-tone subjects had been printed with the chrome-albumen process and powdered for the first etch. The first plate of this series was shown in that condition. The second plate presented the same subjects with the first etch completed. second plate presented the same subjects with the first etch completed. The third showed this as provided with a four-way powdering; on the fourth plate the same subjects were shown as left by the second etch after the first four-way powdering, and on the fifth the same subects were presented as ecthed to "routing" depth in a third etch after a second four-way powdering. The work had been done with the powdering machine in the workshop of the Philadelphia *Press*. The speaker named other establishments

in various parts of the country where this machine was being employed. A full description of this invention is reserved for publication.

The thanks of the meeting were voted to the speakers, and the session was adjourned.

WM. H. WAHL, *Secretary.*

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 4th, 1905.)

DR. EDWARD GOLDSMITH in the chair.

The following reports were adopted:

(No. 2339.) *Schaltung for Induction Coils.* Dr. B. Walter, Hamburg, Germany.

ABSTRACT: The Walter schaltung affords a practical method for reducing the secondary potential of an induction coil, in successive steps, from its maximum potential to its least potential, so that it will satisfactorily operate Roentgen tubes of various resistences when the Wehnelt interrupter is used to operate the induction coil.

The operation of this device with the Wehnelt interrupter in X-ray work has been so satisfactory that although practically the same device has been independently used, the early publication of the same (1900-1901 and 1902) by Dr. Walter, has influenced the Committee in recognizing him as the originator of the device. The report recommends the awarding of the John Scott Legacy Premium and Medal. (*Sub-Committee*, Geo. A. Hoadley, chairman; H. Clyde Snook, Wm. B. Hodge.)

(No. 2359.) *Alternating Current Motor.* M. C. Massie, Washington, D.C. An advisory report.

(No. 2364.) *Graflex Camera.* Folmer & Schwing Mfg. Co., New York.

ABSTRACT: This invention is the subject of a number of letters patent of the United States (1901-1904) granted to W. F. Folmer. The camera, known as the "Graflex," is an ingenious combination of a well-acting, adjustable, focal-plane shutter, with a mirror set at 45 deg. with the axis of the lens, and between it and the shutter. The shutter cannot be set when the mirror is open and there is a free passage of light from the lens, but when the mirror is closed the shutter can be adjusted to the desired width of opening and set ready for exposure.

The mirror forms a light-tight partition between the shutter and the lens. Immediately over the mirror is a ground-glass focussing screen and an ingeniously constructed hood, which folds compactly under the lid of the box and opens out when the latter is raised, forming a dark passage through which the image thrown by the mirror on the ground-glass focussing screen can be viewed and the focus accordingly adjusted. The image is full-size, and the lighting, the composition and the location or pose of any moving detail can be watched and the exposure made at the very instant desired.

When the button is pressed, the mirror flies up and is cushioned without jar, and when it has raised just far enough to clear the cone of ray from the lens, the shutter is released and its opening passes down in front of the sensitive film. In the 4x5 in. size (which the Committee used) this opening can be varied in width from ⅛ inch to 3½ inches, and the speed at which it passes can be varied in six different degrees, so that the range of equivalent exposure varies from $\frac{1}{10}$ to $\frac{1}{1000}$ of a second.

The report pronounces the design and workmanship of the camera to be excellent in every way. The racking arrangement is very rigid, maintaining the adjustment of the lens under all conditions. The adjustments are accurate and few, considering what they accomplish. The whole arrangement is well thought out and the details well proportioned.

The report concludes by recommending the award to the applicant of the Edward Longstreth Medal of Merit. (*Sub-Committee*, Wm. H. Thorne, Chairman; Samuel Sartain, J. W. Ridpath.)

(No. 2367.) *Drawing Pen.* T. Alteneder & Sons, Philadelphia.

ABSTRACT: This invention is the subject of letters patent of the United Statse, No. 480,541, August 8, 1904. Its object is to enable the user to clean the pen without altering the adjustment of the points.

The invention consists of a fixed blade carrying a pivoted blade opening away from the fixed blade and returning to its position and held there by a spring, the distance of the blades apart being limited by a screw.

The report affirms that the pen is well made and is superior to other pens for the same purpose. The award of the Edward Longstreth Medal of Merit is made to applicant. (*Sub-Committee*, Geo. S. Cullen, chairman; Wm. H. Thorne, W. W. Twining.)

(No. 2366.) *Fuel Saving Devices.* Fuel Saving Company, Utica, N. Y.

(No. 2368.) *Process of Flame Regulation.* Byron E. Eldred, Brookline, Mass.

These two reports were referred back to their respective sub-committees for more detailed information

The following report was heard on first reading and held over for final consideration:

(No. 2322.) *Pressed Steel Products.* The Standard Pressed Steel Co., Philadelphia.

WM. H. WAHL, *Secretary.*